CLAIMING A JURIDICAL CONTINENTAL SHELF UNDER ARTICLE 76 OF THE UNITED NATIONS CONVENTION ON LAW OF THE SEA (UNCLOS)

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PREFACE

This technical report is an unedited reproduction of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Geodesy and Geomatics Engineering, September 2002. The research was supervised by Dr. David Wells and co-supervised by Dr. Sue Nichols.

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Abstract

The United Nations Convention on Law of the Sea (UNCLOS) divides the sea floor into zones, one of which, the (juridical) Continental Shelf, only comes into existence if it is claimed by a Coastal State. Article 76 of UNCLOS defines the Continental Shelf in a complex and possibly contradictory manner, one that seemingly requires a great deal of data and scientific analysis. UNCLOS establishes the Commission on the Limits of the Continental Shelf (CLCS) to whom claims are to be submitted for comment. The CLCS has issued *Guidelines* detailing the types and format of evidence they will consider. This thesis analyses Article 76 and the *Guidelines* and creates a model of a process that can be followed by a Coastal State to prepare a Continental Shelf claim that will meet both requirements.

Acknowledgements

I am indebted to my employer, the Canadian Hydrographic Service, for supporting me in this program. While registered for this degree I had the pleasure of writing or co-writing 54 papers with 34 co-authors from 5 countries. I was also able to discuss the full range of hydrographic topics with hydrographers from several countries who were studying at UNB. This is another illustration, if one were needed, of the true trans-nationalism of hydrography as well as the wide range of contacts the university attracts.

I did not come to UNB clutching a fresh undergraduate degree and armed with all the innocent self-confidence that that brings. Rather I came thirty years after being an undergraduate, not sure of how or even if I could handle the incredible technological changes that had come about in the intervening time, especially during the previous fifteen years I had spent in management. I came, too, with a broken body and damaged brain, the first day I could walk un-aided. During the first week: the cleaning man introduced himself, the Chairman invited me to the pub, Dave Wells brought me an exerciser for my shattered wrist, Larry Mayer took me to The Market, Sue Nichols lent me her car and Linda O'Brien eased my way into the system. After a reception like that, my part was easy. A heartfelt Thank You.

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List of Symbols, Nomenclature or Abbreviations

ABLOS	Advisory Board on Hydrographic and Geodetic Aspects of the Law of the Sea
Baselines	Baselines from which the breadth of the Territorial Sea is measured
CARIS LOTS	Law of the Sea Article 76 software
CHS	Canadian Hydrographic Service (Government of Canada)
CLCS	Commission on the Limits of the Continental Shelf (of the UN)
Coastal State	a State with a coast line – (the question of whether a state with a coast line that is not a Party to the Convention will be considered a Coastal State under Article 76 is in abeyance)
EEZ	Exclusive Economic Zone
GALOS	Committee on Geodetic Aspects of the Law of the Sea
Gardiner Line	the sediment thickness line
GEBCO	General Bathymetric Chart of the Oceans
HO	Hydrographic Office
IAG	International Association of Geodesy
IASC	International Arctic Science Committee (parent of Working Group for Arctic Bathymetry)
IOC	Intergovernmental Oceanographic Commission
IHO	International Hydrographic Organization
IMO	International Maritime Organization
L AT	Lowest Astronomical Tide
MBES	Multi Beam Echo Sounder
nm	Nautical Mile (Note that the IHO recommends use of the symbol M)
S44 (or SP44)	IHO Standards for Hydrographic Surveys in various editions
SBES	Single Beam Echo Sounder
States Parties	States which have ratified UNCLOS
UN	United Nations
UNCLOS	United Nations Convention on Law of the Sea (ie the Treaty)
UNCLOS III	The Third United Nations Conference on Law of the Sea (ie the process that created the Treaty)

CHAPTER 1.
INTRODUCTION:

This thesis develops and describes a process to be followed in preparing a submission to the Commission on the Limits of the Continental Shelf (CLCS) delineating a juridical Continental Shelf under Article 76 of the *United Nations Convention on Law of the Sea* (UNCLOS).

In gross terms, the *Convention* grants Coastal States automatic sovereignty over the first 200 nm (nautical miles) seaward from the coast, and may allow them to claim beyond that provided that they can prove that the seafloor they are claiming meets certain conditions. These conditions are defined in Article 76 of the *Convention* (Appendix I). The international community is assured that the conditions have been met by a process that requires the Coastal State to submit a description of the limit and a supporting data set to the CLCS established for that purpose by the *Convention* (Appendix II). Since Article 76 was produced as a compromise between opposing interests, namely those States who wanted there to be wide Continental Shelves and those who were against this, the definition of a Continental Shelf is complicated, perhaps contradictory, demands interpretation and judgement, may require a great deal of supporting data, and at the time of writing, unproven.

> The exact number of States which may be affected by this [Article 76] is not yet clear but, out of approximately 150 Coastal States, about 60 have neighbours closer than 200 nautical miles thereby preventing

> an extended claim, a further 30 or so have a shelf less than 200 nautical miles wide, leaving of the order of 50-60 potential claimants. [Monahan *et al.*, 1999]

Each of these States requires a process to follow in examining their offshore areas and preparing a submission to the CLCS should one prove sustainable. This thesis provides a model for them to follow, examines the more difficult elements in detail and indicates the likely range of spatial uncertainty in the Outer Limit delineated under Article 76.

1.1 Methodology

This work contains extensive quotations from papers in which the author of the thesis was either sole author, lead author or co-author. For ease of reading this document, abstracts are omitted and references have been assembled into one list after the concluding chapter. Where a figure or table was used in more than one published paper, it is included here only once. Consequently, this version is made up of extensive sections of the published papers linked together by new text.

1.2 An overview of the thesis and contributions made

Chapter 1 explains how the thesis is organized. It states that the objective of the work is to develop a model for preparing a claim to a Continental Shelf under Article 76, to examine the more difficult elements in detail and to indicate the likely range of spatial uncertainty in the Outer Limit delineated under Article 76.

Chapter 2, “Continental Shelf as Defined by Article 76 and as Delineated in a Submission to the CLCS” begins with an overview of how boundaries are made in law. It explains that the intent of Article 76 is to assign sea floor of continental origin to Coastal States as Continental Shelves, leaving the deep sea floor to the United Nations (UN). It describes the elements of the definition of a juridical Continental Shelf that attempt to codify this intent. It points out that the Continental Shelf must be delineated and actively claimed by the Coastal State. It goes on to explain that the *Convention* establishes the CLCS to examine claims to a Continental Shelf and make recommendations about their acceptance, and that the CLCS has issued *Guidelines* to define the types of evidence it will examine, and the way the evidence must be presented. The interplay between the two will ultimately determine how Continental Shelves are delineated.

Chapter 3, “Procedures for Preparing a Continental Shelf Submission” solves the problem that although Article 76 gives rules on how a Continental Shelf limit is to be defined, and the *Guidelines* gives rules on the types of data that are acceptable, neither provides a set of instructions on how a limit is to be delineated. Consequently this chapter develops a model of the overall process that can be used and tests the suitability of data sets which are readily available for preliminary investigations.

Chapter 4, “Prepare a Base Map” describes elements of a map that can serve as a base for the delineation exercise. In particular, it describes the two types of baselines used in UNCLOS boundary delimitation, how they are mapped and what the uncertainty in mapping them is.

Chapter 5, “Establish the Zone in which a Continental Shelf Can Exist” deals with the hydrographic element of the Outer Constraint, the 2500 m depth contour. It shows that the uncertainty in locating the contour to present IHO standards is higher than necessary with modern methods and argues for development of a new version of the standard that will incorporate modern depth measurement capabilities.

Chapter 6, “Define the Basis for Going Beyond 200 Nautical Miles” addresses issues of mapping a feature, the Foot of the Slope that may or may not be hydrographic and indeed, may or may not exist. Detecting its presence as an observable physical entity can be problematic and the possibility of it having a mathematical manifestation must be considered. Uncertainty in its location is extremely variable.

Chapter 7, “Uncertainty In Locating The Outer Limit Of A Continental Shelf”, summarizes the uncertainties determined in preceeding chapters.

Chapter 8 Summarizes the material presented and suggests next steps in research towards refining the process modeled herein.

CHAPTER 2
CONTINENTAL SHELF AS DEFINED BY ARTICLE 76 AND AS DELINEATED IN A SUBMISSION TO THE CLCS

One of the most important issues concerning the future of all the ocean activities is the impact of the Third United Nations Conference on the Law of the Sea (UNCLOS III). The outcome of a series of meetings that lasted from 1973 to 1982, the resulting *Convention* (UNCLOS) was the subject of what were probably the most prolonged and intense multinational negotiations in history. The *Convention*, even before it was ratified, completely changed the character of the entire marine sector, and rests as the foundation on which all subsequent international and national marine legislation has been built. [Miles, 1999].

UNCLOS attempts to regulate virtually all activities in the world's oceans, their management and use, in one package. The oceans cover two thirds of the earth's surface, regulate the earth's climate, contain major living and nonliving resources, are the ultimate resting place for many pollutants, and are the surface over which the bulk of the world's trade is carried. Their safe and equitable use, now and into the future, is one of the driving forces behind UNCLOS. The treaty recognizes that the oceans affect the entire planet, not just the 151 Coastal States, by ensuring that not only Coastal States own the oceans. Land-locked and geographically disadvantaged states are granted numerous rights and responsibilities, and the area outside of national jurisdiction is part of the common heritage of mankind.

Prior to UNCLOS III, ocean space was divided into two zones: Coastal States' sovereignty was absolute to a jurisdictional boundary a short distance offshore; outside the boundary, freedom of the High Seas was held to be absolute by some states, but was being challenged by others through isolated actions like the declaration of Fishing Zones. UNCLOS III brought major changes, codifying the further subdivision of ocean space into several zones. Sovereign rights of Coastal States are extended to specified distances offshore, with powers being phased down through several successive zones, with a much greater portion of the seafloor now falling within national jurisdiction. In an attempt to counterbalance possible unfettered expansion, UNCLOS declares the High Seas and the sea floor (The Area), which are outside the zones of national jurisdiction, to be the common heritage of mankind, and establishes the International Sea-Bed Authority to oversee its use.

In general, boundaries are *defined* in theoretical terms by legislation, treaties and agreements, their particulars are *delineated* by a process which applies the definitions to real geography, and the world is advised of their location through *demarcation*, [Nichols, 1983]. Zones in the sea *defined* in the treaty must be *delineated* by the Coastal State according to the wording of the treaty. Unlike land boundaries which can be visited and monumented, marine boundaries can only be *demarcated* on charts, or by lists of coordinates. Delineation of the first three offshore zones (Territorial Sea, Contiguous Zone and Exclusive Economic Zone), although not trivial, is comparatively easy when compared with delineating the Continental Shelf. Doing so involves the disciplines of hydrography, geodesy and geology.

2.1 Historical Context

The intent of the framers of Article 76 is best understood by considering the events that led up to the drafting of the *Convention*. After World War 2, American President Truman declared that the continental shelf adjacent to the USA was “subject to jurisdiction of the United States”, reopening the question of how far seaward a Coastal State exercised sovereignty. Conferences to address this question held in 1958 [United Nations,1958] and 1960 (UNCLOS I and UNCLOS II) did not produce an answer that all States could agree to, but did raise awareness of the importance of the resources of the seafloor. The principal attraction was oil and gas, which were being found in increasing abundance on the physiographic continental shelves. In addition, the possible recovery of “manganese nodules” from the deep sea floor by the USA and Japan helped precipitate UNCLOS III, and the drafting of the present *Convention*. The possibility that the perceived mineral wealth of the deep seabed, as well as the petroleum from the continental shelves, would not benefit the poor nations led them to support holding a third conference (UNCLOS III) and to the introduction in 1967 at the United Nations General Assembly of the concept of the “Common Heritage of Mankind”. This was a concept that polarized both strong opposition and strong support. Rich trading nations saw it as a threat to the concept of freedom of the high seas, while poor or land-locked nations hoped that it would help them obtain the rights to a share of the wealth of the sea floor. Article 76 was written in an attempt to divide the oil-bearing geologic Continental Shelves from the manganese (and it was hoped, other mineral) –bearing deep ocean floor.

Article 76, like the rest of the *Convention*, was written by consensus, and not by majority vote. This has flavored the entire document and must be born in mind while studying any element. Furthermore, the framers of UNCLOS did not start with a blank sheet, but built on existing laws and treaties. Parts of UNCLOS are simple repeats of existing treaties and Conventions (e.g. the Articles dealing with Baselines), parts are the formalizing of customary international laws into treaty form, while other parts, particularly those dealing with the deep ocean, are new.

Partly because of the difficulty in attaining consensus, and partly because some issues are too complex to resolve completely within the text of a treaty, provision is made to allow referral of some issues to certain bodies. Some of these "competent international organization(s)" (e.g. International Maritime Organization (IMO), International Hydrographic Organization (IHO)), existed prior to UNCLOS, while others were established by UNCLOS itself. Of the latter, the most relevant for this thesis is the Commission on the Limits of the Continental Shelf (CLCS) established to examine proposed limits to Continental Shelves. (see Appendix II)

In general terms, UNCLOS automatically grants Coastal States a Territorial Sea 12 nautical miles wide, and a Contiguous Zone, which fringes the Territorial Sea by 12 more miles. Article 15 provides that the boundary between opposite and adjacent States is to be determined from the

> median line, every point of which is equidistant from the nearest points on the baselines from which the breadth of the territorial seas of each of the two States is measured.

States can also declare Exclusive Economic Zones (EEZ) of up to 200 nautical miles width. The boundary between EEZs of opposite or adjacent States shall be established by bilateral agreement, or failing that, by the International Court of Justice. Unlike the three inner zones, the Continental Shelf must be actively claimed, and for some Coastal States will not exist beyond 200 M. Finally, the High Seas comprise all parts of the sea waters that are not included in the EEZ, the Territorial Sea, internal waters or archipelagic waters, while The Area comprises the sea floor outside the Continental Shelves. [United Nations, 1983]

For the Continental Shelf, Article 76 defines the rules that govern the placement of its boundaries; the definition is not straight forward, and may even be contradictory, so that the Outer Limit (of the Continental Shelf) will not be delineated without effort. The *Convention* mandates a process in which a Coastal State delineates its Outer Limit, then demonstrates to the world how it fits the rules defined in Article 76. The Coastal State does so by submitting its description to the CLCS, a body created by UNCLOS. CLCS's task is to examine the delineation in the submission and to make recommendations to the Coastal State regarding whether the description meets the definition described in Article 76. Based on these recommendations, the Coastal State exercises its sovereign right to demarcate its Outer Limit and does so through publishing it as lines on charts and/or lists of co-ordinates, and depositing them with the Secretary-General of the United Nations. This chapter examines the definition described in Article 76 as well as the process of delineation and demarcation, in light of the Scientific and Technical *Guidelines* published by the CLCS. [United Nations, 1999]

2.2 Technical components of Article 76

Article 76 defines an area within which the Outer Limit of the continental shelf may lie. The inner edge of this area is the outer limit of a Coastal State's EEZ, which is at a distance of 200 nautical miles from "the baselines from which the breadth of the territorial sea is measured" (See Chapter 4). The remaining edges to this zone are either bilateral boundaries that will have to be resolved with another state, or a boundary with the United Nations-controlled region of deep sea floor called "The Area", which is the boundary that Article 76 defines.

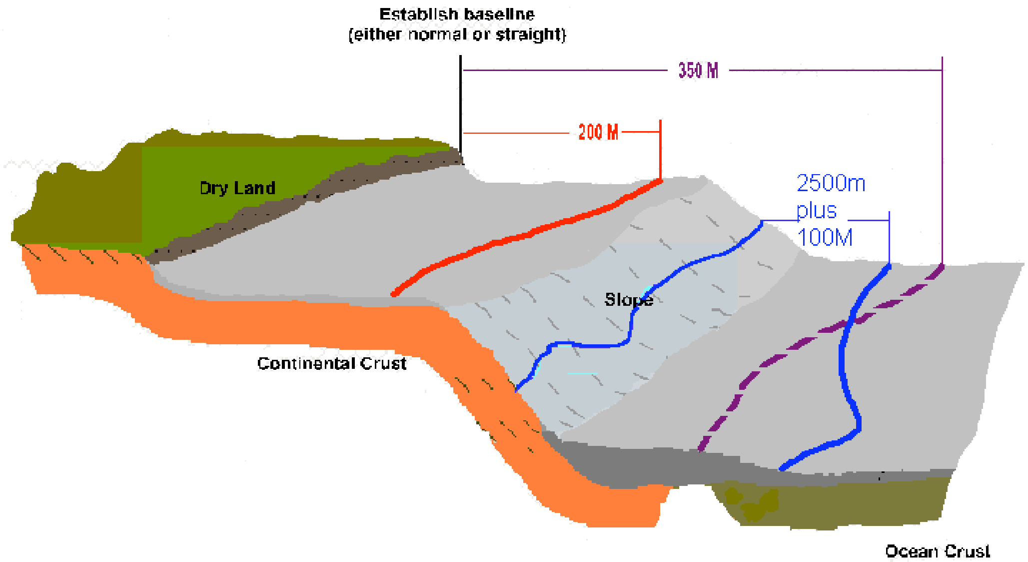

Figure 2.2.1 Three-dimensional sketch of idealised seafloor showing how the 350M line and the 2500 m contour plus 100 nm line are combined to form the Outer Constraint.

Article 76 provides two possible rules for the maximum distance seaward that the Outer Limit can lie. (The fact that there is a maximum is seen by some as a major accomplishment of UNCLOS III [eg McDorman, 2002]). Either a line drawn 100 nautical miles seaward of the 2500 m isobath (bathymetric contour), or a line 350 nautical miles from the baselines from which the breadth of the territorial sea is measured may be used alone or in combination to establish the "Outer Constraint" line. (Figure 2.2.1)

The Outer Limit must lie between the 200 M line and the Outer Constraint. Its location is determined by measuring from a phenomenon known as "the Foot of the Slope", a theoretical physiographic feature on the surface of the sea floor separating the Continental Slope from the Continental Rise. Paragraph 4 of

Article 76 defines the Foot of the Slope as “In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.” Where a Foot of the Slope can be found, an Outer Limit may be located based on either a measurement of 60 nautical miles seawards from it, or the so-called sediment thickness line, a point where the underlying sediment thickness is one per cent of the distance to the Foot of the Slope (Figure 2.2.2). Where a Foot of the Slope cannot be found, it is generally believed that the “evidence to the contrary” clause may be used to establish the continent / ocean boundary on geological/ geophysical grounds. As an exception, over “ridges”, only the 350 nautical-mile line may be used to establish the Outer Constraint. However, the definition of “ridge” is not given and the word “ridge” is used twice in the Article, once modified by “oceanic” and once modified by “submarine”.

The lines claimed as Outer Limits need not be demarcated along their entire length but only at points separated by a maximum distance of 60 nautical miles. Other lines, the Baselines and the 2500 m isobath, must be prepared as continuous lines.

> Clearly, there are both judgmental and more strictly defined elements to the Article, and depending on it's geography and geology, a State may need to invest effort in deciding how best to apply the latitude given. [Monahan et al., 1999]

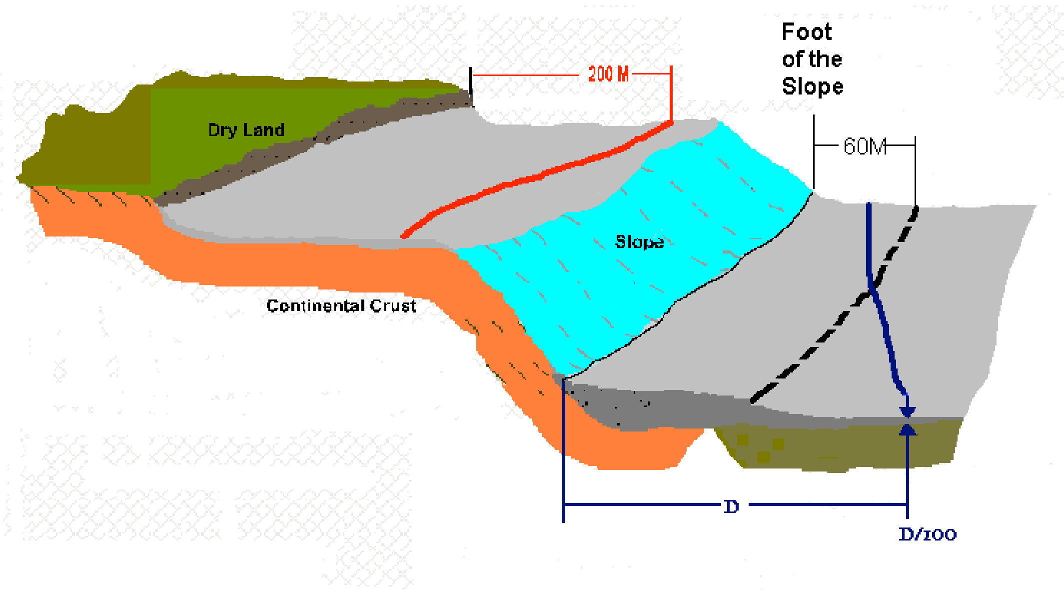

Figure 2.2.2 Three-dimensional sketch of idealised seafloor showing how the Foot of the Slope plus 60 M line and the sediment thickness line are combined to form the Outer Limit

The technical elements defined in Article 76 that must be combined to delineate an Outer Limit are thus:

1 Baselines from which the breadth of the Territorial Sea is measured (Hydrography)

2 Measurement of 60, 100, 200 and 350 nm from Baselines and other lines (Geodesy)

3 The location of the 2500 m Contour (Hydrography)

4 The location of the Foot Of The Slope (Hydrography and Geology)

5 Sediment Thickness at the Foot of the Slope and for some distance seaward. (Geology and Geophysics)

6 Exceptions (when necessary). (a) deciding to use evidence to the contrary (Hydrography, Geology and Geophysics) (b) proving the continental nature of a Ridge (Geology and Geophysics)

2.3 Rules recommended in the Guidelines of the CLCS.

The model of “definition – delineation – demarcation” has been complicated somewhat in the case of Article 76 since the *Convention* establishes the CLCS to examine claims to a Continental Shelf and make recommendations about their acceptance. After its election in March, 1997, the CLCS produced three documents, *Modus Operandi* [United Nations, 1997], *Rules of Procedure* [United Nations, 1998] and *Technical Guidelines*, [United Nations, 1998, 1999], which specify the types of evidence that the CLCS will examine and the way the evidence must be presented. The question is, are these documents part of the definition, the delineation or the demarcation phases? What status do they have, if any? They cannot “define” anything, since that is the role of the treaty makers, not one of the treaty’s creations. Yet in places, the Guidelines can be interpreted as adding to the definition specified in Article 76. (Indeed, part of the protest by the Government of the USA to the “Preliminary” *Guidelines* was that the CLCS was trying to write International Law.) Although individual Commissioners insist orally that the document is only intended to provide “guidance”, (Carrerra, 1998, 1999, 2000, 2001, 2002, Kazmin, 2000, Croker, 2000, 2001) the document itself avers in Paragraph 1.2. that “The Commission prepared these Guidelines for the purpose of providing <u>direction</u> to Coastal States…" (emphasis added) [United Nations, 1999]. The Coastal States of the world may have been waiting for this question to be answered, since they have not been in any hurry to make a submission. Indeed, until the first submission from Russia on December 20, 2001, [United Nations, 2001], it appeared that the first Commission would sit out its term of office without considering a single application of the three documents it had so laboriously crafted.

As an example of where the CLCS, in the technical language of its Guidelines, may step beyond what it is authorized to do, consider the following: Article 16 permits Coastal States to either plot their Baselines

> on charts of a scale or scales adequate for ascertaining their position. Alternatively, a list of geographical co-ordinates of points, specifying the geodetic datum, may be substituted.

But section 3.3.8 of the *Guidelines* specifically indicates that baselines should not be drawn on maps. It is unlikely that the CLCS can create a rule that over-rides the *Convention*.

The *Guidelines* also contain some possible contradictions. For example, Paragraph 3.4.11 states

> There may be no need to submit the data on the full extent of the coastline, a full 2,500 m isobath or the continuous foot of the slope. Only the most seaward points which effectively contribute to the delineation of the outer limit need to be supported.

but according to Paragraph 9.2.2

> the full bathymetric database will be regarded as an essential component of the supporting scientific and technical data.

There is thus a tension between the *Convention* and the *Guidelines*. Those involved in the drafting of the *Convention* have expressed their pride in the “inspired political imprecision” of the text of Article 76. They believe that it was this imprecision that permitted the *Convention* to be signed. The efforts of the CLCS in its publications appear to have been directed towards correcting this imprecision, as if the CLCS members perceived it as a fault. This places Coastal States in a dilemma of not knowing what is required of them. The first, and to date only, actual test of the CLCS was the submission by the Russian federation in December, 2001. [United Nations, 2001]. At the time of writing, the CLCS had examined this submission and made their recommendations to the Government of Russia. These recommendations have not yet been made public, and unfortunately there is no requirement for them to be made public. Since Russia has not declared a Continental Shelf limit based on them, it is assumed that the recommendations did not support the proposed limits.

The role of the CLCS and how it attempts to straddle the line between international law and science is explored in Cockburn et al. [2001] and McDorman [2002].

2.4 Uncertainties in the verbal description of the global process

In geomatics, the term “uncertainty” generally refers to the numerical value of accumulated errors inherent in all measurements. Furthermore, the term "allocational uncertainty" refers to the possibility that a spatial object may be assigned incorrect attributes, but this cannot be quantified. In International Law, uncertainty clearly has a more expansive meaning. Article 76 is deliberately vague, and the very role of the *Guidelines* of the CLCS is not clear. [Cockburn et al., 2001; McDorman, 2002.] Within the *Guidelines* there are contradictions both with other parts of the same document as well as with the *Convention* itself. There is also room for interpretational uncertainty: McMillan [1985] points out that interpreting the term "Foot of the Slope" allows for considerable latitude, while the phrase "sedimentary rock" has more than one possible interpretation. The CLCS itself acknowledges that the term "ridge" is not precisely defined [United Nations, 1999]. There is thus a range of uncertainty, some of which can be expressed in numbers, some of which cannot be quantified.

2.5 Hydrography And Its Role Within The Convention

Although hydrography is commonly known for its role in producing navigation charts for mariners, there are many other elements to the discipline. The definition of hydrography has most recently been refined by Hecht [2001] to read:

> Hydrography is the total set of spatial data and information, and the applied science of its acquisition, maintaining and processing, necessary to describe the topographical, physical and dynamical nature of the hydrosphere and its borders to the solid earth, and the associated facilities and structures.

In this work, the term “hydrography” is used in this all-encompassing fashion. A UN Group of Experts [United Nations Economic and Social Council, 1978] subdivided hydrography into three broad components:

> Coastal hydrography is concerned with the development of ports and harbours, coastal erosion problems, the utilization of harbour and coastal conservation services and, especially, the safety of navigation in coastal waters.
> Off-shore hydrography is concerned with (a) the provision of hydrographic data as an extension of the coastal zone normally encompassing the continental shelf, (b) the development of mineral deposits, including hydrocarbons, and (c) provision of data for fisheries management.
> Oceanic hydrography is concerned with the acquisition of hydrographic data in the deep ocean areas for the depiction of sea-floor geomorphology.

Off-shore hydrography and oceanic hydrography are the arms of hydrography that are primarily concerned with Article 76. Coastal hydrography includes such boundary elements as Baselines from which the breadth of the Territorial Sea is measured.

UNCLOS impacts all of human activity in the oceans. Hydrography impacts, directly or indirectly, much of human activity in the oceans. The two are thus intimately entwined. Many of UNCLOS’s 230 Articles refer to hydrographic products or data, as Table 2.1 summarizes.

2.5.1. Hydrography and Article 76

Article 76 “Definition of the continental shelf” requires active participation by hydrography in a “one time only” establishment of a marine limit. From the early days of UNCLOS lll, papers were produced exploring the inter-relationship between hydrography and elements of UNCLOS, particularly Article 76. For global examples, see United Nations [1993], Kapoor and Kerr [1986], Kerr and

ARTICLE	TITLE	BASE LINE	DISTANCE OR MEASUREMENT	CHART / COORD	TIDE	DRAWN LINE	COAST LINE	DEPTH
2	LEGAL STATUS							
3	BREADTH	X	X					
4	OUTER LIMIT	X	X			X		
5	NORMAL BASELINE	X	X	X	X		X	
6	REEFS	X	X	X	X			
7	STRAIGHT BASELINES	X	X		X		X	
8	INTERNAL WATERS	X						
9	MOUTHS OF RIVERS	X			X			
10	BAYS	X	X		X		X	
13	LOW TIDE ELEVNS	X	X		X			
14	COMB OF METHODS	X						
15	OPPOSITE COASTS	X	X			X	X	
16	CHARTS & COORDS	X		X		X		
22	SEA LANES			X				
33	CONTIGOUS ZONE	X	X					
35	SCOPE-STRAITS	X						
41	SEA LANES			X				
47	ARCH. BASELINES	X	X	X	X		X	
48	BREADTH OF...	X	X					
50	INTERNAL WATERS					X		
53	ARCH SEA LANES			X		X		
57	BREADTH EEZ	X	X					
60	ARTIFICIAL ISLANDS		X					
75	CHARTS/COORDS			X		X		
76	CONTINENTAL SHELF	X	X	X		X		X
83	OPPOSITE COASTS						X	
84	CHARTS / COORDS			X				
85	TUNNELLING							X
94	FLAG STATE DUTIES			X?				
121	ISLANDS				X			

Table 2.1. Relationship between Articles of UNCLOS and hydrography.
(from Monahan and Nichols, 2002)

"Article" is the number of the Article in the Convention. "Title" is an abbreviated version of the Article's title. "Baseline" means the Baselines from which the breadth of the Territorial Sea is measured, which are based on the low water line shown on hydrographic charts. "Distance or Measurement" means that the Article requires that a distance be measured and/or displayed, and doing so may require hydrographic input. "Chart/coord" means that a feature, usually a line, must be displayed on a hydrographic chart, or its coordinates determined. "Tide" means that tidal datum is implicated in the Article. "Drawn Line" means line drawn on a hydrographic chart. "Coast Line" means as depicted on a

hydrographic chart. "Depth" is a depth value on a hydrographic chart or bathymetry map.

Keen [1985], International Hydrographic Organization [1993], Wells and Nichols [1994], Cook and Carleton [2000], and ABLOS [1999]. Particulars of the Canadian situation were elaborated in Macnab [1994), Haworth et al. [1995], and Haworth et al. [1998]. These were perforce predictions, based on analyses of the wording of the *Convention* as it was written. However, the *Convention* itself created a body, the CLCS, that performed its own analysis and issued *Guidelines*, first in provisional form, UN [1998], followed a year later by a final version, UN [1999]. These are an explanation of how the CLCS interprets Article 76 and a set of instructions about the type and form of data and information that a submission delineating a Continental Shelf should contain. Although these *Guidelines* did not alter the message that hydrography has a strong role to play in Continental Shelf delineation, they certainly altered the details of the papers written before their issuance. It is therefore necessary to judiciously apply information contained in papers produced before 1998. It has also proven necessary to re-assess some of the predictions made previously. Some papers produced since the issuance of the *Guidelines* combine both prior knowledge and the contents of the *Guidelines*. [Monahan et al., 1999; Guy, 2000; ABLOS 2001].

2.5.2 Charts as a vehicle for portraying boundaries

> Although charts are often described as navigation documents, common practice of being 'all things to all men' has made them the

de facto chart, map, geographic document of users of the oceans, as well as the government's official statement on most spatial matters. Practically, it makes sense to show fisheries limits, for example, since the fishers and the enforcement vessels will be navigating using charts.

The role of charts as instruments in the construction of boundaries is given legal recognition in the United Nations Convention on Law of the Sea (UNCLOS). Article 5 states 'Except where otherwise provided in this Convention, the normal baseline for measuring the breadth of the territorial sea is the low-water line along the coast as marked on large-scale charts officially recognized by the Coastal State.' The low water line is thus not the same as the shoreline shown on topographic maps, a point that may add to the complications of a coastal boundary making and can lead to differences between neighbouring states which use different methods for determining low water. The Convention goes on to instruct Coastal States to show baselines Territorial Sea, Exclusive Economic Zones and continental shelf limits "on charts of a scale or scales adequate for ascertaining their position." Furthermore, in all these cases "The Coastal State shall give due publicity to such charts". [Nichols and Monahan, 2000.]

2.6 Summary

The *Convention* was written by consensus, not by majority vote, to reach a balance of compromises agreeable to all States. One result is that the wording does not always appear to be precise, and UNCLOS must be read within that context.

UNCLOS divides the world ocean floor into sections: the Territorial Sea, the Contiguous Zone, the Exclusive Economic Zone, the Continental Shelf and The Area. A Coastal State must actively claim the Continental Shelf. Article 76 defines the rules that govern the placement of its boundaries using the language of compromise in a complicated and perhaps controversial manner, so that establishing the Outer Limit is not straightforward. There are both judgmental and more strictly defined elements to the Article.

Technical elements required to prepare a boundary are: Baselines from which the breadth of the Territorial Sea is measured, Measurement of 60, 100, 200 and 350 nm from Baselines and other lines, the 2500 m Contour, the Foot Of The Slope, Sediment Thickness at the Foot of the Slope and for some distance seaward, and exceptions are allowed for.

The general model for establishing boundaries of “definition – delineation – demarcation” has been complicated somewhat in the case of Article 76 since the *Convention* establishes the CLCS to examine claims to a Continental Shelf and make recommendations about their acceptance. The Coastal State demonstrates to the world that it fits the rules defined in Article 76 by submitting its boundary and supporting documentation to the CLCS. The CLCS has produced *Guidelines* regarding the type and amount of data they require: they may have overstepped their mandate in parts of the document, and possibly created confusion between interpretations of the *Convention* and themselves.

CHAPTER 3
PROCEDURES FOR PREPARING A CONTINENTAL SHELF SUBMISSION

Chapter 2 describes how Article 76 gives rules on how a Continental Shelf limit is to be defined and the *Guidelines* show how the CLCS wishes to expand those rules. Neither provides a set of instructions on the process to follow when delineating a limit. One early requirement therefore was to model the process that could be used and to suggest publicly available data sets for preliminary investigations. The papers presented in sections 3.1 and 3.2 undertake these tasks. It is interesting to note that after these two papers were presented at a conference attended by the majority of the membership of the CLCS, [Advisory Board on Law of the Sea, 1999] the final version of the CLCS *Guidelines* [UN, 1999] contained process diagrams very similar to those in the two papers. These papers were also used in the development of CARIS LOTS (Law of the Sea Tool Kit), [Halim et al., 1999] where the model was used as part of the top-down design and publicly available data sets were incorporated into the software package.

<u>3.1 A Model For Using Publicly Available Data And Methodologies To Begin Preparing A Claim</u>

Extracted from:

Monahan, D., M.S. Loughtridge, M.T. Jones and L. Mayer (1999).

3.1.1 The situation a Coastal State faces

States deliberating on making a claim are faced with:

a) understanding Article 76 and the *Guidelines* within the context of their own geography,

b) deciding, within the judgmental elements of Article 76 and the *Guidelines*, which features they may wish to attempt to claim as part of their legal continental shelf

c) examining the existing data to determine whether it will support a claim

d) where necessary, planning for and collecting additional data,

e) assembling the data into a supported and defensible claim and

f) submitting a case,

all within ten years of ratifying the Convention.

[Section 3.1 of this thesis] examines the first four steps in this process and develops a model that can be used as an overall guide to preparing a claim. A State intending to prepare a claim will probably wish to use the most economical and productive approach, one that uses the best elements of all possible methods in a synergistic manner. The iterative model developed here applies several approaches in a mutually supportive flow that will lead to an effective claim, supported by appropriate interpretations of the evidence available. It also addresses the questions of deciding where data are needed, and when to invoke the "evidence to the contrary" clause and move from morphology into developing the geological case.

3.1.1.1 The steps in making a claim

Coastal States will begin the process of preparing a claim from different positions in terms of their expertise in the subject and the amounts of data available to them, to say nothing of the physical setting of their margin. All States will follow the steps shown in Table 3.1.1; they will probably step through this table again and again, at each step improving their knowledge of their continental shelf, until they are satisfied that they have sufficient evidence to support their claim.

Table 3.1.1 Overview of steps in preparing a claim

	STEPS in preparing claim
A	**PREPARE BASE MAP**
B	**ESTABLISH THE ZONE POSSIBLE**
C	**DEFINE BASIS FOR GOING BEYOND 200 NAUTICAL MILES**
D	**PREPARE OPTIONS BEYOND 200 NAUTICAL MILES**

The first two iterations through this model can be done using existing publicly available data, as this paper shows. Completing these first two iterations quickly and at low cost will permit identifying where more detailed work is required. An exposition of how these two iterations can be made is given in the following sections while a summary of the key elements of the iterative model is to be found in Table 3.1.2.

3.1.2. First Iteration

3.1.2 Objective

The first objective is to decide whether an extended continental shelf may exist adjacent to a Coastal State and the approximate zone within which it might fall.

3.1.2.1 Prepare a base map

Sea floor physiography is shown on bathymetry maps, which are available in highly variable quality, scale and coverage depending on the area of the world being examined. Bathymetry of all the world ocean has been mapped to at least a “first look” stage through an international IHO/IOC collaborative exercise known as the General Bathymetric Chart of the Oceans (GEBCO). This is a good starting point for any preliminary investigation, although where more recent or better scale maps exist, they should be used. In paper form, any map series permits gaining an overall appreciation of the geography involved, and permit hand drawing and measuring. The paper chart version of GEBCO was published by the Canadian Hydrographic Service in the 1980s [IHO, IOC and CHS, 1984]. It is now being updated in digital form through a product called the GEBCO Digital Atlas with new versions being published on CD-ROM at three yearly intervals by the British

Table 3.1. 2: Iterative model for preparing a claim

[Note: within the table, lower-case letters within square brackets refer to the chapter of this thesis that discusses the item]

A	**PREPARE A BASE MAP** [Chapter 4]	
1	ON EXISTING MAP DRAW	SHORELINE BATHYMETRY BILATERAL BOUNDARIES
2	DO BASELINES EXIST?	IF YES, INCLUDE ON BASE MAP IF NO, USE SHORELINE AS INTERIM MEASURE
B	**ESTABLISH THE ZONE POSSIBLE** [Chapter 5]	
1	DRAW 200M LIMIT	*DOES IT INFRINGE ANOTHER STATE'S 200M LINE? IF YES, DRAWN MEDIAN LINE AND STOP (NO CLAIM CAN BE MADE INSIDE ANOTHER STATE'S 200M LIMIT)
2	DRAW 350M LINE	
3	DRAW 2500m + 100M LINE	
4	DRAW OUTER CONSTRAINT LINE (MOST SEAWARD COMBINATION OF B2 AND B3)	*DOES IT INFRINGE ANOTHER STATE'S CONSTRAINT LINE? IF YES, DRAW MEDIAN LINE. WHERE MEDIAN LINE IS NEEDED, IT BECOMES A CONSTRAINT LINE
5	SKETCH EXTENSIONS TO BILATERAL BOUNDARIES	
C	**DEFINE BASIS FOR GOING BEYOND 200 NAUTICAL MILES** [Chapter 6]	
1	MAP 'FOOT OF THE SLOPE' ALTERNATIVES USING BATHYMETRY	*IS IT SEAWARDS OF 200 MINUS 60M? IF NO, CONSIDER 'EVIDENCE TO THE CONTRARY'
D	**PREPARE OPTIONS BEYOND 200 NAUTICAL MILES**	
1	DRAW 'FOOT OF THE SLOPE' + 60M	*IS IT SEAWARDS OF OUTER CONSTRAINT LINE? IF YES, GO TO NEXT ITERATION
2	DRAW SEDIMENT THICKNESS LINE [Sediment Thickness Line Chapter 7]	USE SEDIMENT MAPS AS AN INTERIM MEASURE
3	COMBINE D1 AND D2	TAKE MOST SEAWARD COMBINATION TO CLAIM FOR FURTHEST EXTENT
4	RESULT [Chapter 10]	MAP SHOWING POSSIBLE CLAIM INCLUDING a) AREA WHERE 'FOOT OF THE SLOPE' + 60M WILL SUFFICE b) AREA WHERE SEDIMENT THICKNESS DATA WILL BE NEEDED c) AREA WHERE 'EVIDENCE TO THE CONTRARY' WILL NEED TO BE CHECKED
*FOOTNOTE: IN CASES WHERE THE RESPONSES TO TESTS B1, B4, C1 AND D1 VARY ALONG THE LINE BEING TESTED, THE INSTRUCTIONS APPLY TO THAT PART OF THE LINE TO WHICH THE RESPONSE RELATES		

Oceanographic Data Centre [IOC, IHO and BODC, 1997 and Jones, 1997]. The CD-ROM version allows for calling up only selected contours, say the 200 m and 2500 m, to help emphasize or clarify a point. It also includes a facility for making distance measurements directly on the screen to evaluate the feasibility of including a feature based solely on distance. As an example of how the GDA can be used as a basemap, Figure 3.1.1 shows a portion of GEBCO bathymetry off eastern Canada.

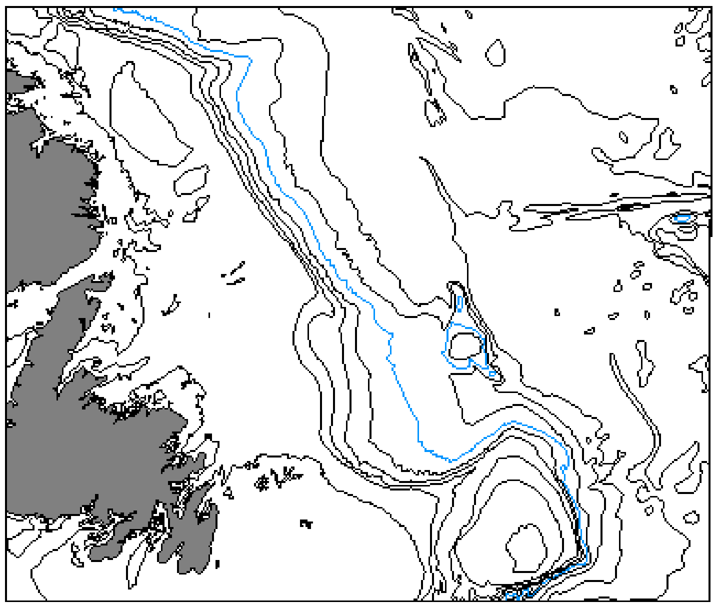

Figure 3.1.1 As an example of how the GDA can be used, a portion of GEBCO bathymetry off Eastern Canada is shown.
Contours are at 200m. 500m and every 500m thereafter. 2500 m contour is shown in blue [gray if reproduced in black and white].

3.1.2.2 Establish the zone possible

The inner limit to an extended continental shelf is the 200 nautical mile line which marks the outer edge of a Coastal State's EEZ. In areas where an EEZ is less than 200 nautical miles wide since it terminates at a boundary with another State, there can be no claim.

The outer constraint line is made up of the most seaward combination of a line 350 nautical miles from the baselines and the 2500 m plus 100 nautical mile line. Neither of these lines can infringe on similar lines drawn by neighbouring States and where they do, some median line will have to be drawn. At this stage the median line is for planning purposes: if at a later date, the extended continental shelf reaches the median line, it will probably become the subject of an agreement between the adjacent States. There is one limitation imposed here; over 'ridges', only the 350 nautical mile line is permitted as the constraint. "Ridges" are discussed as part of the "Areas to include" exposition below.

An extended continental shelf around an island will have no lateral limit, but where two States abut (e.g. Canada - USA), a lateral limit will consist of the extension seaward of the boundary they share within their EEZs. For planning purposes, a simple geometric extension will suffice.

Drawing a 350 nautical miles line is straightforward. The 2500 m plus 100 nautical miles line can raise the issue of isolated elevations. Figure 3.1.2 continues the example area shown in Figure 3.1.1 and shows the alternative 2500 m plus 100 nautical miles line that including or not including such elevations can produce. Alternatives like this are discussed under "Areas to include" below.

3.1.2.3 Define the basis for going beyond 200 nautical miles

3.1.2.3.1 The Foot of the Slope

Taken together, the inner limit and the outer constraint line produced in the preceding section circumscribe an area within which a State may be able to prove that an extended continental shelf exists. That proof and any claim are based on the location of a geomorphic feature, the Foot of the Slope, which may or may not exist on any stretch of continental margin. Paragraph 4(b) of Article 76 defines the Foot of the Slope as follows:

> "In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base".

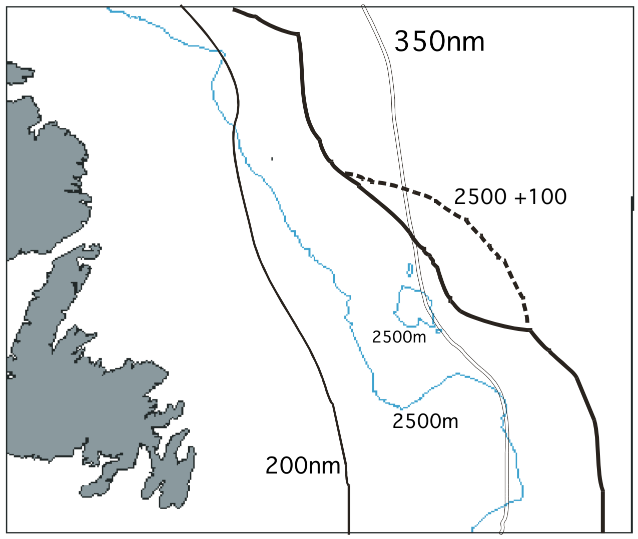

Figure 3.1.2. Summary of lines that can be quickly sketched on the base map using the GEBCO Digital Atlas.

Inner fine line labeled 200 nm marks the EEZ. [Blue (gray if reproduced in black and white)] line is the 2500m contour (contours except the 2500m have been omitted for clarity). Fine double line labeled 350 nm is the 350 nautical mile constraint. Heavy solid line labeled 2500 +100 is the 2500m contour plus 100 nautical miles line: heavy dashed line shows an alternative more likely position.

Note that there is no quantification of the gradients involved: all that is required is to find the point where the gradients change the most. Nor is there any specific depth associated with the Foot of the Slope, although Article 76 does give some guidance in that it uses the word "base", meaning towards the deeper part of the Slope. "Evidence to the contrary" is not defined, but inclusion of this phrase in the definition leaves scope for using arguments other than morphometric gradient determinations. The *Guidelines* provide extensive elaboration of "Evidence to the contrary". Essentially, they support an argument that the edge of the continental crust may not have a surface expression manifested as a geomorphic Foot of the Slope. Rather the edge of the continental crust may be found by other, primarily geophysical, means.

At this preliminary stage, a State will first examine the sometimes complicated question of whether a morphometric Foot of the Slope exists and it's location, before addressing the necessity and value of invoking the 'Evidence to the contrary' clause. Finding a Foot of the Slope is a multi-part problem, beginning with finding the appropriate break in slope in any one place complicated by two ancillary problems, namely, what to do with isolated elevations, and whether a continental shelf is formed on an 'ridge' or not.

3.1.2.3.2 Areas to include

Some continental margins will consist of a single cohesive block, but many will have elevated features separated from the main margin by deeper sea floor. Article 76 gives some guidance on how these are to be dealt with in Paragraph 6 where it acknowledges the existence of

> submarine elevations that are natural components of the continental margin, such as it's plateaux, rises, caps, banks and spurs.

The Commission's [1999, i.e. final] *Guidelines* elaborate as follows:

> the Commission will base its views on submarine elevations mainly on the following considerations:
>
> (a) In the active margins, a natural process by which a continent grows is the accretion of sediments and crustal material of oceanic, island arc or continental origin onto the continental margin. Therefore, any crustal fragment or sedimentary wedge that is accreted to the continental margin should be regarded as a natural component of that continental margin;
>
> (b) In the passive margins, the natural process by which a continent breaks up prior to the separation by seafloor spreading involves thinning, extension and rifting of the continental crust and extensive intrusion of magma into and extensive extrusion of magma through that crust. This process adds to the growth of the continents. Therefore, seafloor highs that are formed by this breakup process should be

> regarded as natural components of the continental margin where such highs constitute an integral part of the prolongation of the land mass. Paragraph 7.3.1

These clarifications make it evident that the geology of an elevation and not its physiography will determine whether it can be included or otherwise within a continental shelf. Although neither the *Guidelines* nor Article 76 specifically say so, it is implicit that a Foot of the Slope will occur, if it occurs at all, on the seaward flanks of these isolated continental elevations.

The question of whether an extended continental shelf is formed on a 'ridge' or not is important since if it is, Article 76 restricts the outer constraint line to the 350 nautical miles cut-off, and prohibits the use of the 2500 m plus 100 nautical miles line. The CLCS debates at great length what is meant by the term "oceanic ridge" in [both preliminary and final *Guidelines*, before concluding in Paragraph 7.2.11 [1999]

> As it is difficult to define the details concerning various conditions, the Commission feels it appropriate that the issue of ridges be examined on a case-by-case basis.]

[In the early iterations of the model] a Foot of the Slope can be mapped on geomorphic grounds along ridges that adjoin a continent and possibly an island, perhaps occurring as far seaward as the 2500 m plus 100 nautical miles constraint.

Clearly, the inclusion of elevations and ridges can greatly influence the ultimate size of a claim and must be considered carefully.

3.1.2.5 Prepare options beyond 200 nautical miles

The reasoning in this section should be applied to prepare a draft map showing the area within which the final Outer Limit claim will fall and the options available for where a Foot of the Slope will occur and where "evidence to the contrary" might usefully be invoked. Doing so will require some maps and tools, as discussed below.

3.1.2.5.1 Working example using publicly available bathymetric maps

A very tentative Foot of the Slope line can be produced using the bathymetric contours on GEBCO. On a contour map, gradients are steeper where contours are closer together and less steep where contours are further apart (provided of course that the contour interval is the same). In theory, the Foot of the Slope may therefore be shown at the place where the more closely spaced contours of the Slope give way to the more widely spaced contours of the Rise. The horizontal scale means that measurements between contour lines cannot be very accurate but some continuity can be established. Working with contour maps alone, it is possible to arrive at more than one interpretation of the Foot of the Slope, which shows where effort will have to be focussed as the investigation continues.

Figure 3.1.1 provides an example of this off Eastern Canada. In the northern part of the diagram the situation is fairly straightforward: a linear continental slope with regular contours. The zone within which the Foot of the Slope must fall is easy to determine at this scale. Moving south, a widening of the spacing between contours complicates the situation, with no easily apparent zone within which the Foot of the Slope can easily be fitted. Even further south, the presence of an isolated elevation, Orphan Knoll, illustrates the issue of whether isolated elevations may be included. Bathymetry alone will not clarify whether these are continental fragments or not, and at this stage they can be left as questions, or the preliminary investigation can expand into a literature search to determine what is known of the geological history and composition of the feature in question. In the example, Orphan Knoll would be shown to be continental fragments (data from drill cores, gravity, magnetic and seismic data), meaning the Foot of the Slope can be unambiguously extended to encompass it. If the geological and geophysical data did not exist or were scarce, the origin of these features would have to be investigated.

The Foot of the Slope line produced as described can be plotted onto the map of the possible zone within which the extended continental shelf may occur as shown diagrammatically in Figure 3.1.3. This is a valuable exercise since it shows:

a) Areas where the morphological Foot of the Slope may be inside the 200 nautical miles line. These are obvious candidates for sediment thickness investigations, and less obviously, possible candidates for where "evidence to the contrary" may be applied.

b) An area where the Foot of the Slope is seaward of the constraint line and simple bathymetry will suffice.

c) A situation where two locations of the Foot of the Slope can be predicted depending upon whether an isolated elevation is included or not. These are areas where "evidence to the contrary" may be applied, and areas where some geological evidence will be needed.

d) An area where the Foot of the Slope is difficult to determine from contours.

None of this is to say that a Coastal State would not examine all possible avenues for all of its geographic area. It may well do so, but this process shows where emphasis can most advantageously be placed soonest.

3.1.2.6 Results of first iteration

The results of the preliminary investigation should yield a small scale map showing very approximate outer limits, areas where different parts of Article 76 apply and a zone wherein the Foot of the Slope is probably to be found. It will also show the intent to try to include certain physiographic features within the claim. It will not have investigated sediment thickness in any detail, nor the use of "evidence to the contrary", but will have identified where they might be important. (Carpenter et al., 1996, provide an example of results of this level of investigation for the eastern continental USA. Monahan and Macnab, 1994, do the same for Canadian waters.)

3.1.3: Second Iteration

3.1.3.1 Reasoning

States will enter this second loop armed with some small scale planning maps, produced during the first iteration, that largely reveal where different portions of Article 76 can be applied, where some decisions need to be made and where further investigation is needed.

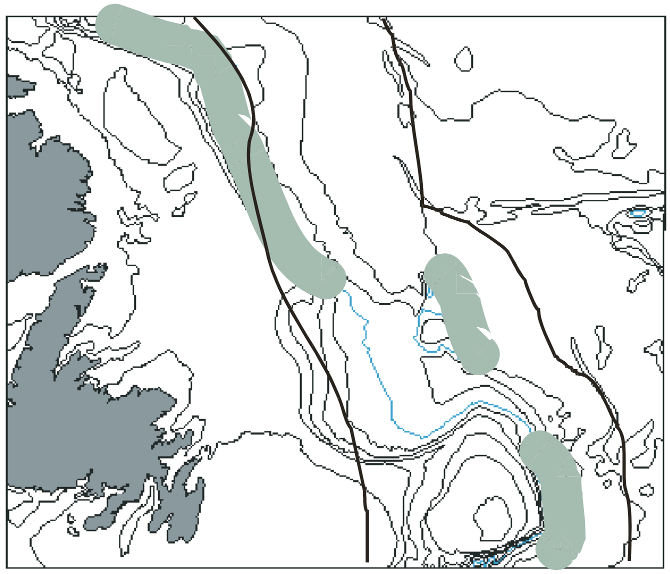

Figure 3.1.3. The zone where the claimed Outer Limit of the Continental Shelf lies will be between the EEZ and the outer constraint line, both shown as solid medium lines.

Shaded areas indicate where the Foot of the Slope, or in early iterations, the Base of the Slope, may lie, based on analysis of the contours. Other areas shown on this diagram but not labeled are discussed in the text.

As an example, consider the 2500 m contour. The preliminary investigation will have shown approximately the region where it will be used to determine the outer constraint line. There will be cases where it is not used at all, the 350 nautical miles being further seawards, and energy can be focussed on other parts of the claim. Where it is to be used, the contour will need to be supported by echo-sounding data. The following questions then arise. Is there enough data of acceptable quality and spatial layout? Has more data been collected but not incorporated into the maps used in the preliminary investigation?

Because it may be based on the same data set, these questions can also be applied to determining the Foot of the Slope on morphologic grounds. The two may not be strictly comparable since Foot of the Slope is probably more demanding of data than is the 2500 m contour.

3.1.3.2 Results

Production of small scale maps that illustrate approximately where a state may make a claim, that show the sections of Article 76 that apply to a State's offshore, and that allow planning for more detailed investigations at further iterations of the model. By the end of the second iteration, a start will have been made in identifying existing data that might be available for use in developing the claim.

3.1.4. Succeeding Iterations

Deciding how far to continue through succeeding iterations will involve judging the amount of territory that might be claimed against the difficulty and expense of making the claim. For some States, the first two iterations will have produced a convincing picture to proceed, while others will want to investigate more fully, while still not committing many resources. Both will probably continue almost automatically to the next iteration, investigating sediment thickness and "evidence to the contrary" more fully using the available data.

As the picture develops, succeeding iterations will be used to narrow down the zone of uncertainty and point the way to where more data are needed. At each iteration, greater detail will be built into the suite of maps and their supporting data bases until eventually sufficient information is available to support the claim. Where justified by the potential benefits of the claim, such iterations will invariably involve the collection of field data to refine the Outer Limit and to resolve ambiguities.

[Monahan, Loughridge, Jones and Mayer, 1999]

<u>3.2 . An examination of publicly available bathymetry data sets using digital mapping tools to determine their applicability to Article 76 of UNCLOS.</u>

Extracted from:

Monahan, David and Larry Mayer (1999).

3.2.1 Options available to a Coastal State

To make a claim under Article 76, a State is faced with either:

a) Using existing maps and the contours on them

b) Making new maps from existing data

c) Collecting an entire suite of new data and produce contours from it or

d) Using a combination of old and new data to produce contours

The advantages and disadvantages of these approaches are summarized in Table 3.2.1. Deciding which of these to use will consist of trying to optimize the quality of existing maps and contours and the degree to which they might be improved by the recompilation of existing data sets or the collection of entirely new data, the complexity of the morphology of the sea floor in the area, and on financial considerations. The size of the ocean and the slow speed of data acquisition from ships, to say nothing of the expense, dictate that most States will probably begin with examining Option 1) use existing maps and the contours on them followed by exploring Option 2). [Section 3.2 of this thesis] examines these two options through the example of publicly available data and tools.

3.2.2 Sources of existing maps and bathymetry data

The generally internationally recognized series of bathymetry maps, GEBCO, [IHO, IOC and CHS, 1984] is up to 23 years old in places, although parts of it are updated regularly. Other IOC programs have produced maps in selected areas, with more under active development (for example, see IOC and HDNO, 1981). Some Coastal States have national bathymetry mapping programs (e.g. Japan has extensive coverage at scales of 1:20 000 to 1:200 000), but these are the exception rather than the rule. Clearly, worldwide bathymetry maps at any detailed scale is extremely variable in its quality and availability.

In addition to maps, a number of digital bathymetry databases are readily accessible. Holcombe and Moore [2000] give an extensive listing of International, US and European sources. Gridded data sets that are easily accessible include ETOPO5 and Predicted Bathymetry [Smith and Sandwell, 1997].

It might be argued that most maps and databases that have been produced in the past are out of date since new technology is rapidly becoming available. With the exception of predicted bathymetry the new technology still has to be operated from ships, and ships unfortunately are slow and expensive. Eventually, all the sea floor will be covered by the new data, but for some time bathymetry maps interpreted from single beam data will remain the most widely available maps of the sea floor. In any case, a Coastal State will begin it's planning to prepare a claim, and its planning of where to deploy the new technology, by examining existing maps and data bases.

Table 3.2.1. Comparison of possible options for data and maps on which to base a claim under Article 76 and the Guidelines.

OPTIONS	USE EXISTING MAPS AND DATA SETS	PERFORM NEW INTERPRETATIONS	COLLECT NEW DATA	COMBINATION
FACTORS				
COST	Insignificant	Low	High	Varies
TIME FRAME	Immediate	Up to One Year	Several Years	Several Years
AVAILABILITY	Available	Present to one year	Several Years	Several Years
SCALE - DETAIL	Low	Better	High	High
ACCURACY	Low	Better	High	High
COMPLETENESS	Low	Better, Variable	Can be total	High to total
SUPPORTING MATERIAL REQUIRED BY CLCS				
META DATA	May not be available	At least partly available	Available	Available
ESTIMATES OF ERROR	May not be possible	A posteriori possible	Possible	To be developed
INTERPRETATION METHOD	May not be known	Describable	Describable	Describable

3.2.3 Operations: Applying the tools to the data

Given there are data sets available in the public domain, what information can be extracted from them that will be of value in the early stages of preparing a claim, using existing tools? More specifically, we set out to determine how, within the zones where the different sections of Article 76 apply, different data sets compare. Knowing more about these data sets will help in deciding how far through the process they can be used.

For this exercise we used data from the following sources:

Off Eastern Canada: Data from a region of the Scotian Shelf was extracted from both the ETOPO-5 data set and the Predicted Topography data set of Smith and Sandwell [1997]. Both of these data sets were downloaded from the NGDC web site. A national data set consisting of single beam sounder data collected over the past 30 years was supplied by the Geological Survey of Canada [Ron MacNab, pers comm.]. Finally, GEBCO contours were extracted from the GEBCO-97 Digital Atlas CD [IOC, IHO and BODC, 1997].

Off New Jersey, USA: Data for the New Jersey margin was also extracted from the ETOPO-5, Predicted Topography and GEBCO databases. In addition, a high-resolution bathymetric data set which included both multibeam and single beam sounder data was extracted from NGDC's new Coastal Relief Model CD's.

The tool we used, Fledermaus, like some other modern digital mapping tools, produces screen size, multicoloured three-dimensional images that are dynamic, they can be rotated, stretched and moved, and the entire image can be "flown" through, as if in a helicopter flying over land. These types of images do not reproduce well on a static medium like paper, and we cannot reproduce them here. Examples and a "movie" of a flythrough are always available at [www.ivs.unb.ca]

These data sets will be similar to those held by some Coastal States and some of the source data will in fact be the same. For several reasons, often there are data already ashore but not yet incorporated in data set Coastal State is using, usually from other agencies, universities or from industry. There is also some degree of correlation between the publicly available data sets, since some ship tracks are used in more than one of them. At the early stages, using whichever is most readily accessible will not detract from the final result.

Grid size in some of the data sets is predetermined. Users may be able to make grid cells larger, but seldom can they be made smaller. As scale is increased, grid size will begin to effect the accuracy of the resulting contours and Foot of the Slope, but at the early investigative stages, this is not an issue.

3.2.4 Findings

Comparing data sets is not straightforward. This study concentrated on comparing the 2500 m contour produced by or contained within the data sets, in part because of the importance of the 2500 m contour in determining the outer constraint line, in part because the 2500 m contour is more tangible than the Foot of the Slope. Contours can be compared visually, but no real statements can be made about which is the more likely to be true since the data sets all contain some common source depths. To overcome this, a modern multibeam data set [NGDC Coastal Relief Model, Vol. 2.] was plotted together with the older public data. The multibeam should be better positioned, internally consistent, suffer little from beamwidth problems, and have no gaps in its coverage of the sea floor.

Plotting the four 2500 m contours together allowed comparison in both qualitative and quantitative terms. Visual inspection shows that the three ocean-scale data sets interweave each other and form a corridor or confidence zone approximately 10 km wide. Naturally, these contours contain only long wavelengths. The much shorter wavelengths captured by the multibeam contour weave amongst the other three, and appear to be centred on the zone created by the older three. Assuming the multibeam-derived contour to be true, the horizontal distances from it to each of the other contours were measured at intervals of 1 km along a 70-km stretch. The magnitude of these differences, as shown in Figure 3.2.1, is never more than 10 km, and is usually less than 5 km. From a histogram of these differences, (Figure 3.2.2) it appears that the predicted bathymetry has a systematic horizontal bias of 2-3 km. GEBCO and ETOPO5 do not appear to have a bias, with GEBCO being more closely located to the multibeam contour.

From these limited observations, it can be concluded that publicly available bathymetry data is of high enough quality to permit a Coastal State to produce a credible early version of its 2500 m contour. Multibeam data will be required to produce a soundly based contour in the spaces left by the older data sets. Multibeam is likely to find areas of contour that protrude seawards of the existing contours.

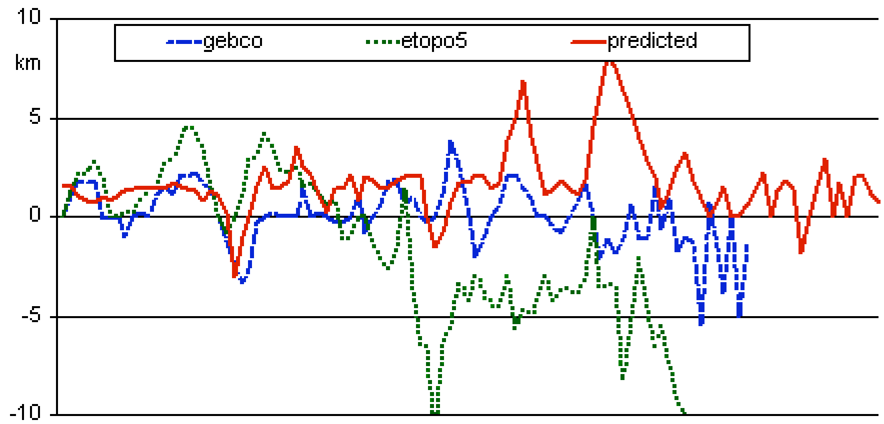

Figure 3.2.1 Magnitude of horizontal differences between 2500 m contours produced from ETOPO5, NOAA Predicted (Satellite) Bathymetry, GEBCO and a multibeam survey from NGDC Coastal Relief Model.

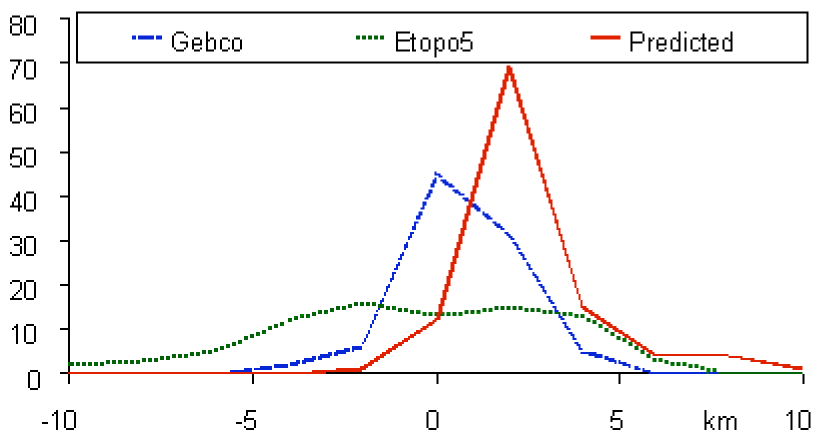

Figure 3.2.2 Histogram of horizontal differences between 2500 m contours produced from ETOPO5, NOAA Predicted (Satellite) Bathymetry, GEBCO and a multibeam survey from NGDC Coastal Relief Model.

The multibeam data is considered as true and the displacement of the other three measured seawards (+) or landward (-).

Other operations with the tools

With a sophisticated set of tools there are other operations that can be performed on the data sets that can be used to help establish a claim.

For example, finding and justifying the Foot of the Slope will be extremely difficult in many locations, and any device that contributes to the solution is valuable. This set of tools can automatically create gradient maps that are colour coded according to maximum gradient through each data point. (Figure 3.2.3). Maps produced this way show that gradients on the Continental Slope are dominated by local maxima on the walls of canyons. Away from canyons, colour changes on these maps reflect changes in gradient that can be examined as possible Base of Foot of the Slope locations.

Profiles are drawn instantly through the depth data and through the gradient data. Profiles of physiography can be examined for Foot of the Slope locations, which may be confirmed by profiles across the gradient surface. These profiles are colour-coded by gradient as is the surface, and patterns of changing colours are instantly recognisable and help narrow the search for maximum change of slope.

Another way to use the existing data and software to close in on the Base of the Slope (if not the Foot of the Slope) is a feature that highlights cells with large differences between the values of soundings in that cell. Cells with a large range of sounding values will not contain the Foot of the Slope. The tool also highlights cells with no differences between the soundings, and those cells will not contain the Foot of the Slope either. The resulting map is divided into three bands, the middle one of which must contain the Foot of the Slope. The band can be narrowed through varying the thresholds in the cells in the fringing bands. A variant on this is to calculate the standard deviation of the depths in each cell and work with them rather than the range of depth values.

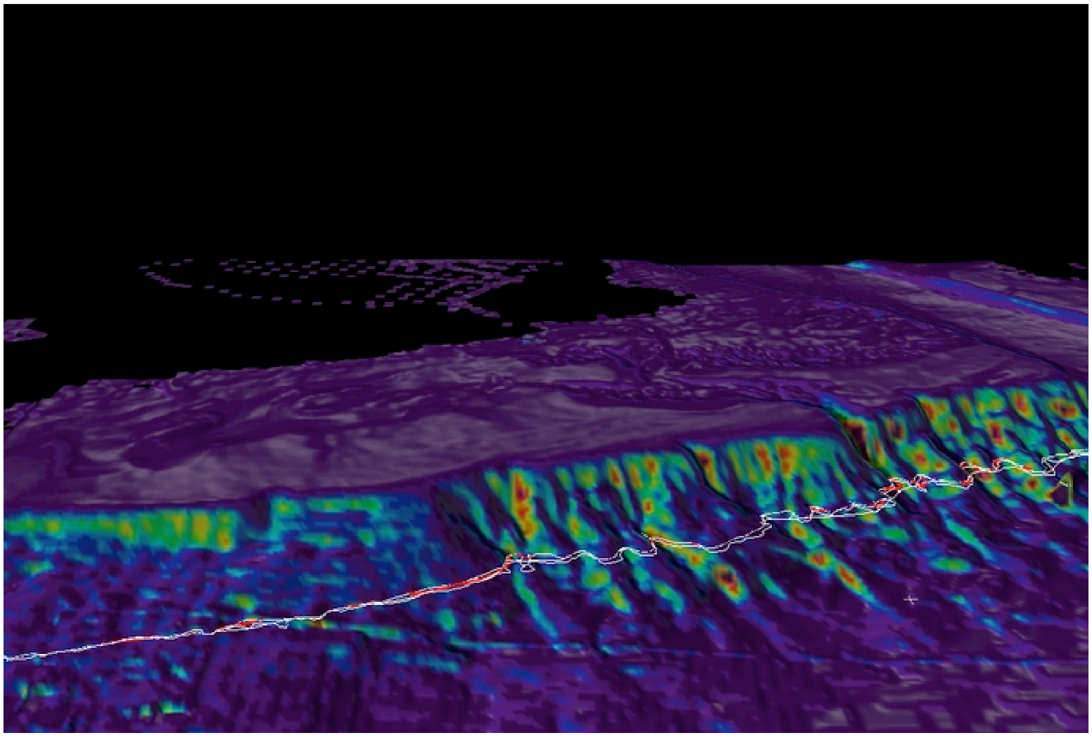

Figure 3.2.3. Gradients map and profile of the area south of Nova Scotia, Canada, drawn using Fledermaus.

Gradients are portrayed by colours, with blue being the lowest and red the highest. Gradients are highest on canyon walls. Rapid change in color along the profile indicates areas of highest change of slope. In the map view, the three lines are the 2500m contour from the ETOPO-5 and Predicted Topography data sets and from GEBCO.

3.2.5 Conclusions

[Section 3.2] has examined the feasibility of using existing maps and data sets together with a modern digital mapping suite to perform the early stages of preparation of a case for an extended Continental Shelf. For the two areas we examined, both off the east coast of North America, the three data sets (ETOPO-5, Predicted Topography and GEBCO) produced results that were similar enough that using any one of them, for the first iteration of preparing the case, would be justifiable and useful. Given that the area tested is among the better sounded sections of the ocean, this

> conclusion may not apply everywhere. We intend to perform similar tests in other areas.
>
> Multibeam data has been shown to add a considerable amount of short wavelength detail to the 2500 m contour in the one area tested. The much more sinuous contour produced from the multibeam data was generally located within the combined positional envelope created by the three older data sets. It did extend beyond this envelope in localised protuberances in both landward and seaward directions.
>
> Using a powerful readily available mapping tool like Fledermaus permits rapid cartographic portrayal of the 2500 m contour and offers a variety of promising methods that will allow analysis of the other morphologic elements of Article 76, the Base and Foot of the Slope. To be useful in this regard, a tool must provide for visual techniques, such as the rapid portrayal of profiles, as well as those based on calculations on the data. For instance, this paper discussed the use of automatic gradient mapping, in map and profile views. There are also a number of operations that can be performed on data that are gridded, and these will grow in number over the next few years as more work is done to meet Article 76 requirements.

[Monahan, and Mayer, 1999]

The sections above have developed a process model within which preliminary work can be begun on examining a Coastal State's offshore and determining whether it is likely to be able to claim a Continental Shelf. It has been shown that there is no need to assemble new data during the early stages since adequate publicly available data exists. This data can be assembled into a base map of the likely area containing the Continental Shelf and the area within which the Outer Limit may lie can be determined by constructing the Constraint lines at 350 nm and the 2500 m isobath plus 100 nm. Physiography within the area may include ridges and/or isolated elevations, which at the early stages need only be identified as requiring more detailed examination at a later stage. The likelihood of there being a physical expression of the Foot of the Slope can be determined, and the need for using “evidence to the contrary” examined. Results from this stage will be small-scale planning maps, which can be refined through successive iterations of the model. It has been shown that a great deal can be done using publicly available data sets: the products of the early iterations can be used to plan further data acquisition. The model can be incorporated into specialized software suites [eg Halim et al., 1999; Collier et al., 2002] or used with existing software.

Many of the elements of the model are straight forward and easily accomplished. A few are more complicated and require further elaboration. This thesis next examines in greater detail the more problematic components used to establish a Continental Shelf in the model described in Table 3.1.2.

3.3 Summary

States who may have a Continental Shelf must: develop an understanding of Article 76 and the *Guidelines*, decide which features they may wish to attempt to claim, examine existing data and where necessary plan for and collect additional data, assemble the data into a supported and defensible claim and submit a case. Although they have rules, there is a need for a model of the process to be followed. This chapter has developed one and suggested publicly available data sets for initial iterations

The model has four major steps, prepare a base map, establish the zone possible, define basis for going beyond 200 nautical miles and prepare options beyond 200 nautical miles. Each are described as are questions of where data are needed, and when to invoke the “evidence to the contrary” clause. The first two iterations through this model can use existing publicly available data. Further iterations include may require making new maps from existing data, collecting an entire suite of new data or using a combination of old and new data.

This chapter compared three existing bathymetric data sets with new MBES data and showed that the publicly available data is of high enough quality to permit production of credible early versions of maps. Multibeam data adds a considerable amount of short wavelength detail.

The model developed here was used in the development of CARIS LOTS (Law of the Sea Tool Kit).

CHAPTER 4
PREPARE A BASE MAP

Section 3.1.2.2 describes the preparation of a base map. One element, Baselines, which are important features in many elements of marine law and have a small role in Article 76, require further elaboration. This chapter explains their derivation and use.

UNCLOS adopts, largely verbatim as codified in the Convention resulting from UNCLOS I [United Nations, 1958], the concept of using baselines to separate land from sea. Although UNCLOS refers to them as “Baselines from which the breadth of the Territorial Sea is measured”, the breadths of the Contiguous Zone and the EEZ are also measured from them. Baselines impact the size of the Continental Shelf in one and possibly two ways, since its inner bound is the 200 nm marking the limit of the EEZ, and the 200 nm is measured from the Baselines. Additionally, one of two alternative Outer Constraints that might form the Outer Limit of the Continental Shelf, the 350 nm line, is measured from the Baselines.

4.1 Where does the sea legally begin?

The law, national and international, must define the geographic areas it applies to. UNCLOS spends some energy on the starting point, which is roughly the place where land ends and sea begins. How to express this interface in legal terms has not proven to be easy, since the physical reality is not clean-cut. There are issues in the vertical dimension since the level of the water is in constant change and is referred to different datums, and in the horizontal dimension due to the complex sinuosity and presence of islands along the "shoreline". In response, the law has attempted to be realistic and produce a result that is applicable and defensible. It has developed the concept of a baseline; one side of the baseline is either the land of the Coastal State or the internal waters of the Coastal State: the other side is sea, in fact part of the Territorial Sea of the Coastal State.

4.2 The impact of uncertainties in the locations of "baselines from which the breadth of the Territorial Sea is measured" on the outer limit of the juridical Continental Shelf.

Extracted from:

David Monahan, Susan Nichols, Sam Ng'ang'a and Rob van de Poll (2001).

4.2.1. Introduction

In its elucidation of the rules that define the outer limit of a legal Continental Shelf, Article 76 imposes a constraint seawards of which the claims cannot be made. Coastal States have some flexibility in that the outer constraint can be composed of either a line 350 nautical miles (M) from the "Baselines from which the breadth of the Territorial Sea is measured" or a line 100 nm seaward of the 2500 m-depth contour. Exceptionally, over "ridges", the Outer Constraint is restricted to 350 nm, which may increase the areas where the 350 nm cutoff is applied. While not all Continental Shelves will extend as far as the Outer Constraint, it is possible that for those that do, the locations of points on baselines will have some influence on the location of at least some portions of the Outer Limit of the juridical Continental Shelf.

[Section 4.2] examines where and to what extent uncertainties in the location of baselines propagates as uncertainty in the location of the outer limit.

4.2.2. Baselines within UNCLOS

4.2.2.1 The need for and use of baselines within Article 76

Those who opposed the idea of Coastal States claiming wide margins wanted restraints placed on how wide the shelf could become, and their actions forced the inclusion of two constraints. One, founded in the belief that the intent of Article 76 was to give the physical continental margin to the Coastal State, is the 2500 m isobath +100 nm line.

Isobaths seemed too esoteric to others who insisted on a measurement that could be more easily understood, i.e., one that went from some known point to the Outer Constraint. Since the intent of Article 76 was to grant to the Coastal State the “natural prolongation” underwater of its landmass, the “shoreline” seemed a reasonable known point to start from. However, the shoreline had become codified through several Articles into “the Baselines from which the breadth of the Territorial Sea is measured”. No doubt there was considerable debate over how far the measurement should go, with 350 nm being the distance immortalized in the treaty.

4.2.2.2. The need for and use of baselines within UNCLOS

Baselines from which the breadth of the Territorial Sea is measured had been included in the Convention because treaties that refer to geographic entities (e.g., international air travel) need to identify the spatial area they apply to. The framers of UNCLOS were faced with defining in legal terms where the sea and land met in order that the contents of the Convention would be clearly applied to an area that could be legally accepted as being the sea.

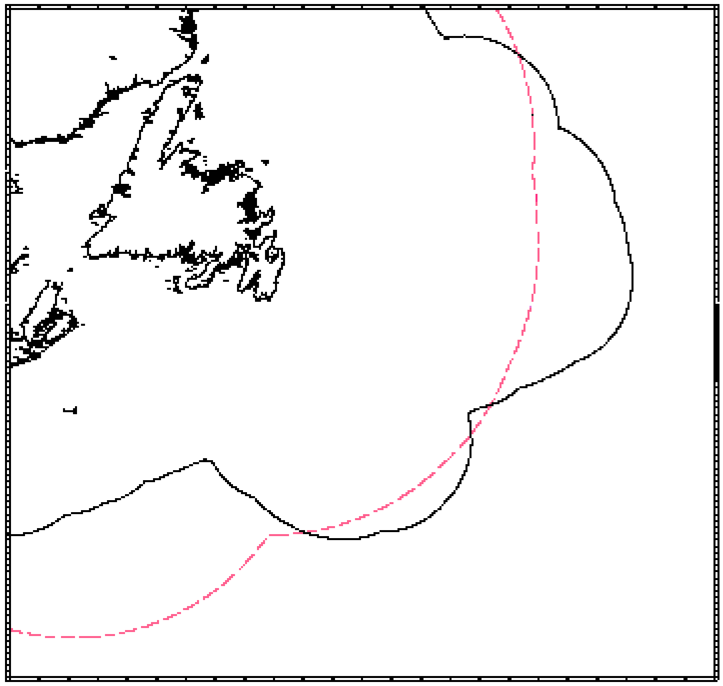

Figure 4.2.1 Sketch illustrating the concept that the 2500 m + 100 nm (dark line) and the 350 nm from the baselines (dashed line) combine to form the Outer Constraint.

Both the customary and codified law of the sea has attempted to be realistic and produce a result that is understandable and defensible. The framers of UNCLOS took *'the low-water line along the coast as marked on large-scale charts officially recognised by the Coastal State"* as the "normal" component of the legal division between land and sea. Most Coastal States produced or participated in the production of "large-scale charts" through their Hydrographic Offices (HO) or through agreements with one of the larger HOs. As members of the International Hydrographic Organization (IHO), the HOs produced charts to a uniform international standard promulgated by the international body that the UN accepts as the world authority on hydrography.

However, '*the low-water line along the coast…"* did not cover all possibilities. How far upstream from the ocean did a river become part of the Coastal State, for instance? Furthermore, before the drafting of UNCLOS, many Coastal States had claimed jurisdiction over certain bays, which they had defined by "straight baselines" across their mouths, and these existing baselines had to be incorporated into the Convention [see, e.g., Reed, 2000]. The International Court of Justice in the *Anglo-Norwegian Fisheries Case* had also recognized that an island fringed coast such as Norway could be enclosed with Straight Baselines. Consequently, in addition to the "Normal" Baselines along the low-water line, Coastal States have the option of constructing Straight Baselines that join points on the mainland, on islands, on certain rocks and on certain low tide elevations. This has the advantage of straightening complicated stretches of shoreline and resolving, to some extent, the status of waters between islands and other bodies of land.

While Article 5 specifying the use of the low water line on charts as Normal Baselines was straightforward, the use of Straight Baselines required more complex treatment. Straight baselines could not be drawn haphazardly, and the Convention needs 3 Articles to provide rules governing their generation. [Beazley, 1971]. Coastal States may use one or both types of baselines. The net effect is that UNCLOS allows the definition of a line, parts of which follow the cartographic portrayal of the low water line, parts of which may consist of straight lines joining points on the low water line, as the boundary between land and sea. Collectively, this line is referred to as The Baseline, and in general conversation the distinction between straight and normal baselines is not made.

4.2.3. Baselines and the CLCS *Guidelines*

4.2.3.1. Role of the CLCS vis-à-vis baselines

While it is clear that the CLCS has the outer limits as its purview, it cannot make any recommendations concerning inner limits, nor over limits where the Continental Shelf of opposite or adjacent states abut. What about the baselines, which are well away from the CLCS's mandated area, but which nevertheless might impact the outer limit? In its *Guidelines*, the CLCS addresses this as follows:

> Paragraph 3.3.1. The Commission is not entitled by the Convention to issue any recommendations with respect to the delineation of baselines from which the breadth of the territorial sea is measured. Its role is limited to a potential request for information about the

geodetic position and definition of the baselines used in a submission made by a Coastal State.

Paragraph 3.3.2. There are only two instances in which the Commission might request geodetic information about baselines. First, it must be satisfied that the test of appurtenance has been positively met. Secondly, if the 350 nm limit is employed as a constraint in a submission, the Commission might also find it useful to make recommendations in relation to the methodology employed in the delineation of this limit.

4.2.3.2. Demands imposed by the CLCS's Guidelines

3.3.9. The Commission remains open to consider all forms and combinations of methods used to determine the position of baselines by a State in a submission. The Commission may request during the consideration of a submission the following geodetic information about baselines:

Source of the data;
Positioning survey technique;
Time and date of the survey;
Corrections applied to the data;
A priori or a posteriori estimates of random and systematic errors;
Geodetic reference system; and
Geometric definition of straight, archipelagic and closing lines.

4.2.4. The Physical Manifestation of the Baselines

4.2.4.1. Normal baselines

Normal baselines are defined in Article 5 as '*the low-water line along the coast as marked on large-scale charts*'…However, until recently, there has been no uniform international practice as to which 'low water' to use. Some HOs have used a low-water line showing the water level at "lowest normal" tides, i.e., the level that sea water normally reaches, with the time period that defines "normal" being one day to two years. Others have favoured the use of Lowest Astronomical Tides (L.A.T.), the lowest [predictable water level, ignoring un-predictable meteorologically –induced variations] in the 18.61 year metonic cycle. The IHO has recently [International Hydrographic Organization, 1997] adopted a resolution that will see the Lowest Astronomical Tides (L.A.T.) become the world standard, but it will take many years before existing charts based on other datums can be converted to LAT.

Tide ranges are measured at permanent gauges at selected points, and the duration of time over which the gauge operates contributes to the value of its results. Spatial distribution of tide gauges is not uniform, with busy ports and active shipping channels usually benefiting from a concentration of them, while remote areas have only a few widely scattered instruments. During a hydrographic (depth) survey, a temporary gauge will be established in the proximity of the survey; the data it records is used to adjust the depths collected as well as providing input to the tidal model for the region. Tidal range along the shoreline between gauges is estimated or predicted by models, and there are several different models in use. Using the predictions to correct raw numerical depths to a common datum is straightforward; applying them to determine the position of a low water line which might occur only once a year or once every 18.61 years, is much more difficult.

In the *Guidelines*, the CLCS deals with this situation as follows:

> Paragraph 3.3.4. ... The Commission acknowledges that many different definitions are used in State practice and that some define a lower tidal datum than others.
>
> Paragraph 3.3.5. The Commission feels that there is a uniform and extended State practice which justifies the acceptance of multiple interpretations of the low water line. All of them are regarded as equally valid in a submission.

4.2.4.2. Straight baselines

Coastal States are welcomed by Article 14 to use a combination of Normal and Straight baselines "to suit different conditions", thereby avoiding the complications imposed by the physiography of some coasts. There are a number of UNCLOS Articles that provide instruction on how to construct these straight baselines. Collectively the ambiguity of these clauses will likely allow Coastal States to take considerable latitude in what they choose their baselines to be. It is only where their choice of baselines impacts upon another Coastal State, or where other States strongly object to the territory included by the use of straight baselines, that there may be some challenge to any claimed baselines.

4.2.4.3. The choice of which type of baseline to use

While there are many other considerations when choosing to use either straight or normal baselines, in terms of the 350 nm constraint, the choice of normal or straight baselines only makes a difference to the outer location in cases where points on the baseline are further than 60 nm apart. Seaward of every pair of points on a baseline, be it normal or straight, it is possible to construct a rectangle the long side of which is 350 nm and the short side is the distance between the two points. The outer short side of the rectangle forms the 350 nm constraint, as long as the distance between the two points is less than 60 nm, since Article 76, Paragraph 7 specifies "*The Coastal State shall delineate the outer limits of its continental shelf, … by straight lines not exceeding 60 nautical miles in length..".*

In cases where the spacing between two points on a straight baseline exceeded 60 nm, a Coastal State could simply pick an intermediate point on the straight baseline, and construct two rectangles based on the three points. However, if the two points are on a normal baseline, once they are more than 60 nm apart, a rectangle can no longer be constructed. What had been the straight outer edge of the rectangle is transformed into a line composed of the intersection between a 60 nm long straight line and two arcs 350 nm long centered on the two baseline points. In this case, the outer edge line is closer to land than the straight edge of a rectangle would be, and that might mean a reduction in a Coastal State's Continental Shelf.

4.2.4.4. Number of baseline points required

Delineation of the limits based on baselines. i.e., the Territorial Sea, the Contiguous Zone, the Exclusive Economic Zone and the 350 nm Constraint use successively fewer points on the baselines. The paradox is that while delineating any of these limits does not require baseline points for the entire coastline, finding the critical points may require mapping the points along the entire coast.

4.2.5. Error budget for baselines as they affect the 350 nm constraint

In order to classify the uncertainties, the authors have first outlined the steps in delineating and demarcating a 350 nm constraint line. These are summarized in Figure 5.2.3. In this paper, we only consider uncertainties due to Steps 1-6, i.e., uncertainties arising from the way in which baseline points, and in particular the critical baseline points, are defined and delineated.

The Error Budget for Baselines is thus broken into two components:

> Definition and Selection of the critical baseline points to be used as ends of the arcs creating the 350 nm line, including the definition and selection of procedures and standards to be used (e.g., use of digital or graphical means)
>
> Delineation and Selection of the actual critical baseline points (including delineation of other baseline points for selection of critical points and in the case of Normal Baselines, charting the actual low water line)

4.2.5.1. Definition and Selection Uncertainties:

The Definition and Selection components can be dominant yet are difficult to put numbers on. If a single point that could be used is missed, the area it generates [could be] larger than [that generated by] the errors in all the points that are used. How could points be "missed"? A revised tidal regime could permit inclusion of a point, for instance, at some future date. In the Arctic and Labrador, Canada has not charted all low tide elevations that might become critical baseline points. [Gray, 1994]

More important is the approach used in defining points. Should there be an aggressive search for end points that will push the Territorial Sea (and thus the 350 constraint line) as far offshore as possible or should an approach that stays close to shore be used?

Will Straight Baselines be used? The approach chosen represents a significant strategic-political uncertainty.

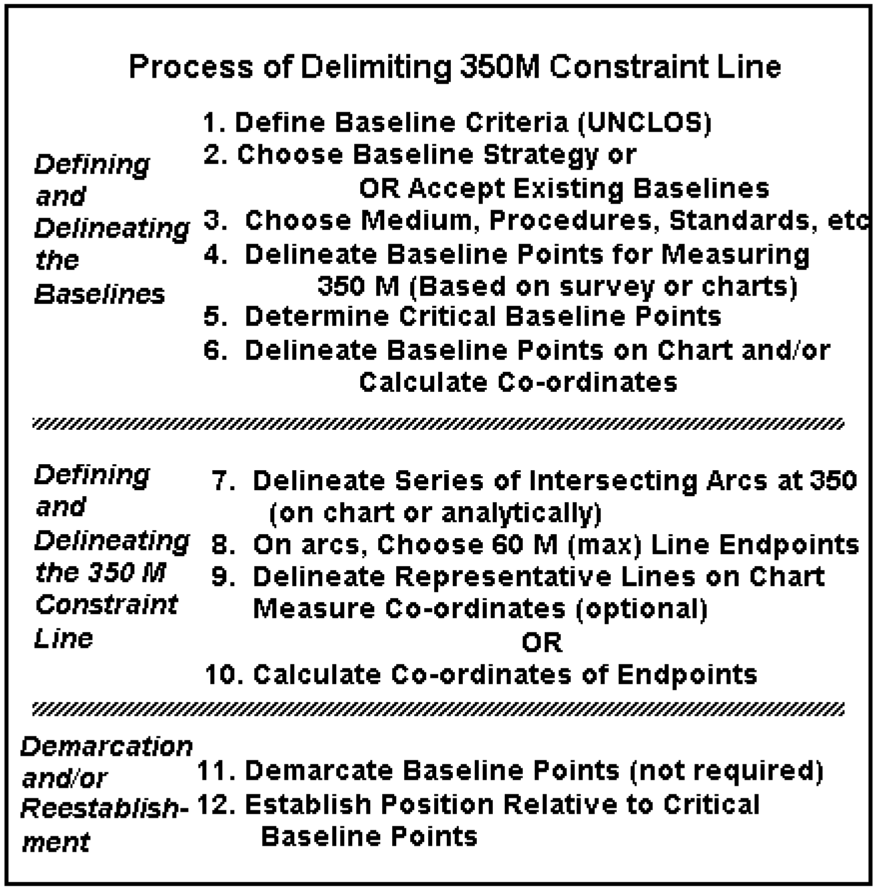

Figure 4.2.3 Process of Establishing Constraint Lines

4.2.5.2. Delineation Uncertainties

Under spatial uncertainties, it is usually the manifestation of errors in the horizontal direction that is paramount, since these dictate the accuracy of the positions of lines drawn at various distances. Consider a shore face sloping at some angle x. A difference of y in the vertical measurement of tide, for example, will manifest itself as a horizontal displacement of magnitude = y/tan x, perpendicular to the shore face. The vertical difference could arise from uncertainty in measuring tide, or uncertainty in determining vertical datum. Magnitudes of vertical differences are likely to be in the decimetre range, and Table 4.2.1 summarises the magnitudes of horizontal uncertainty these would generate.

Table 4.2.1: Horizontal uncertainty that vertical differences in tidal heights can cause over various bottom slopes

Vertical Difference -m Tides	**Bottom Slope in degrees**						
	15	10	5	2	1	0.5	0.25
	Resulting horizontal uncertainty m)						
0.1	0.4	0.6	1.1	2.9	5.7	11.5	22.9
0.2	0.7	1.1	2.3	5.7	11.5	22.9	45.8
0.3	1.1	1.7	3.4	8.6	17.2	34.4	68.8
0.4	1.5	2.3	4.6	11.5	22.9	45.8	91.7
0.5	1.9	2.8	5.7	14.3	28.6	57.3	114.6
0.6	2.2	3.4	6.9	17.2	34.4	68.8	137.5
0.7	2.6	4.0	8.0	20	40.1	80.2	160.4
0.8	3.0	4.5	9.1	22.9	45.8	91.7	183.3
1	3.7	5.7	11.4	28.6	57.3	114.6	229.2
1.5	5.6	8.5	17.1	43	85.9	171.9	343.8
2	7.5	11.3	22.9	57.3	114.6	229.2	458.4

If we assume that differences are usually less than 0.3 m and slopes generally greater than 0.5 degrees, then this part of the error budget is not a major issue in Law of the Sea continental shelf determinations.

UNCLOS Article 16 permits Coastal States to either plot their Baselines

> on charts of a scale or scales adequate for ascertaining their position. Alternatively, a list of geographical co-ordinates of points, specifying the geodetic datum, may be substituted.

Although section 3.3.8 of the *Guidelines* [UN, 1999] specifically indicates that baselines should not be drawn on projected maps and used in a submission, various countries might still be employing cartographic solutions to endpoint location. Assume that a baseline endpoint is 0.25 mm in diameter when drawn on a nautical chart that is at a scale of 1:10000. This represents an error of 2.5 m in endpoint location. However, if a small scale map is used (1:100000 or 1:150000) so that one can see a considerable length of coast, then the precision of baseline points varies between 25 m and 37.5 m respectively.

4.2.6. Further Uncertainties

The previous section gives some examples of uncertainty in factors that contribute to the location of the 350 nm Constraint. Table 4.2.2 is a preliminary attempt to capture all the contributing uncertainties.

Table 4.2.2: Uncertainties in the 350 nm constraint line due to Baseline delimitation

	STAGES	TYPES OF UNCERTAINTY
1	BASELINE UNCERTAINTY	
1.1	CHOOSE BASELINE CRITERIA	LEGAL UNCERTAINTY (STRAIGHT OR NORMAL BASELINES) POLITICAL/STRATEGIC UNCERTAINTY (HISTORICAL BAYS, MAXIMUM LIMITS)
1.2	CHOOSE MEDIUM, PROCEDURES, STANDARDS	DATA UNCERTAINTY (AGE, ACCURACY, AND SCALE OF CHART DATA) STANDARDS UNCERTAINTY (DATUM DEFINITION, LINE TYPES) CARTOGRAPHIC UNCERTAINTY (SCALE, RESOLUTION, PROJECTION) OTHER DATA UNCERTAINTY (AGE, ACCURACY, AND SCALE OF CHART DATA) OTHER STANDARDS UNCERTAINTY (LINE TYPE, LINE WIDTH, TANGENT POINTS)
1.3	DELINEATE BASELINE POINTS- CHART AND/OR CO-ORDINATES	DESCRIPTION ERROR MEASUREMENT ERROR TECHNOLOGY UNCERTAINTY (COMPASS, SCALES, ROUND-OFF)
2	350 N.MI LIMIT UNCERTAINTY	
2.1	DEFINE BASELINE POINTS FOR MEASURING 350 N MILES	MEASUREMENT ERROR MATHEMATICAL MODEL UNCERTAINTY (# OF ITERATIONS, METHODOLOGY)
2.2	DELINEATE INTERSECTING ARCS AT 350 N MILES	MEASUREMENT ERROR MATHEMATICAL MODEL UNCERTAINTY (# OF ITERATIONS, METHODOLOGY)
2.3	ON ARCS, CHOOSE 60 N MI (MAX) LINE ENDPOINTS	MEASUREMENT ERROR MATHEMATICAL MODEL UNCERTAINTY (# OF ITERATIONS, METHODOLOGY)
3	PHYSICAL DEMARCATION UNCERTAINTY.	
3.1	DELINEATE REPRESENTATIVE LINE CHART OR COORDINATES	CARTOGRAPHIC UNCERTAINTY (SCALE, RESOLUTION, PROJECTION) DESCRIPTION ERROR
3.2	DEMARCATE BASELINE POINTS USED	CARTOGRAPHIC UNCERTAINTY (SCALE, RESOLUTION, PROJECTION) DESCRIPTION ERROR MEASUREMENT ERROR
3.3	ESTABLISH POSITION RELATIVE TO REPRESENTATIVE LINES	MEASUREMENT ERROR

4.2.7 Conclusions

1. The uncertainties can be classified as those due to definition and selection (independent of Coastal State coastline) and those due to actual delineation and selection of actual points (i.e., location on a chart of the defined baselines for a specific coastline).

2. The definition related uncertainties are largely a result of:
   how "low water on a large scale chart" is interpreted
   choice by a Coastal Nation of the political strategy to employ (e.g., maximum enclosure)
   choice by a Coastal Nation of the type(s) of baseline to use
   choice of medium

3. The delineation related uncertainties are a result of:
quality of the low water datasets (e.g., tidal models)
actual characteristics of the shoreline (e.g., slope, configuration)
selection of critical baseline points
actual drawing of lines and calculation of co-ordinates

[Monahan, Nichols, Ng'ang'a and van de Poll, 2001]

4.3 Impacts of baselines on other limiting lines

Although the entire baseline is important for delineating the edge of the land or inland waters of a Coastal State, the amount of it that is used to delineate the successively further offshore zones decreases as the distance offshore increases. Only a few points contribute to the delineation of the Outer Limit. (e.g. Off the Pacific coast of Canada, only 17 points on the baselines are required to produce the 200 nm line).

Extracted from:

Monahan, David and D E Wells, 2001.

In terms of the lines that are drawn based on the baselines (i.e. outer limits of Territorial Sea, Contiguous Zone, EEZ and the 350 nm constraint to the Continental Shelf), the choice of normal or straight baselines does not often make much difference to the final location. Differences that do occur decrease with distance offshore. This arises since the straight lines join points on the same low water line as used by the "normal" baseline, and they are the points of maximum seaward protrusion. Swinging arcs from these points creates the fringing zones, with most of the baseline, be it straight or normal, having little effect. The greater the diameters of the arcs, the fewer points are needed. (See Figure 4.3.1). The effect has been likened to running a wheel with a radius equal to the width of the zone being mapped (i.e. 12, 24, 200 or 350 nm) along the baseline and having the center of the wheel trace out the edge of the zone. Indentations of certain sizes are smothered whether or not straight lines are used. Only a few critical points on the baselines contribute to the outer limits.

4.3.1 Effect of selection of critical points

What effect can a mislocation of any of the critical points have? Possibly the most extreme case would be a point at the end of a slender peninsula or island, from which an arc of 350 nm would sweep out a semicircle forming an outer constraint. If the point were located 10m further seawards, the difference in area that the Coastal State might claim would be only 6 sq nm. Given that actual differences are likely to be much smaller than this, putting much effort into improving this is [of] questionable value.

What matters is the selection of points that are to be used as the ends of baselines. Most Coastal States will expend energy on some optimization strategy that maximizes the area inside the baselines. Doing so requires a careful examination of tidal datums, the presence of any physical features, and the social and economic considerations permitted. One approach is to produce a number of possible baselines and calculate the areas enclosed by each, and iteratively search for the largest. CARIS LOTS software includes this capability [van de Poll et al., 2000].

[Monahan and Wells, 2001]

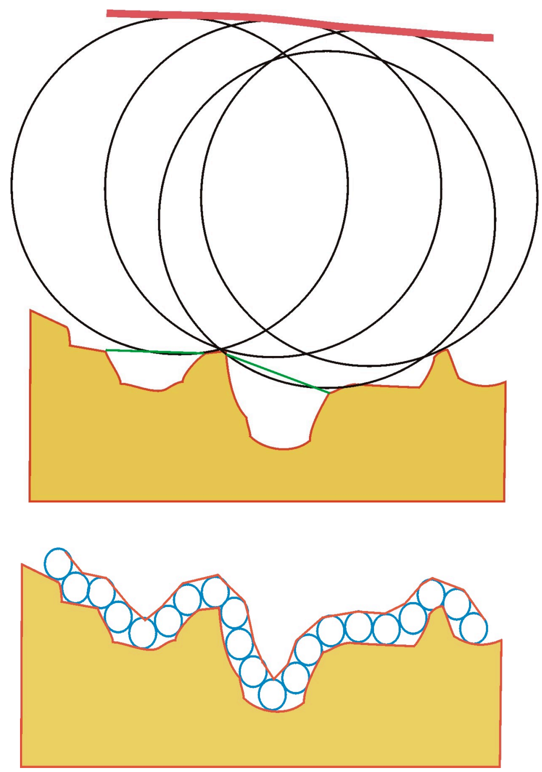

Figure 4.3.1 Sketches showing the reduction in the number of critical points along a shoreline with increasing distance to offshore limits.
Land is the same in each. Lower sketch shows 12 nm line, upper shows 200 nm line.

4.4 Summary

The concept of using baselines to separate land from sea was codified in UNCLOS I. Baselines impact the inner bound of the Continental Shelf (i.e. 200 nm) and may determine the Outer Constraint where it is the 350 nm line. Normal Baselines are the low-water line along the coast; exceptionally, they may be straight lines joining points along the shore. A combination of normal and straight Baselines is permitted. The CLCS *Guidelines* aver that the Commission may make recommendations about Baselines in cases where the 350 nm line is used as the Outer Constraint. Uncertainty in delineating Baselines is dominated by definition and selection of points to use, with measurement or delineation uncertainties having only a minor effect. Selection of optimal points on the Baselines to use as the basis for constructing the 350 nm line depends on the geometry of the shoreline and off-lying features. Once selected, uncertainty in their location effects the overall area of the Continental Shelf to a small degree. Every geographic area will have to be assessed and optimized through a number of iterations of modeling which Baseline point to use.

CHAPTER 5.
ESTABLISH THE ZONE IN WHICH A CONTINENTAL SHELF CAN EXIST

In describing how the zone possible is established, Section 3.1.2.3 mentions but does not elaborate on the 2500 m depth contour. The 2500 m contour plus 100 nautical miles is an alternative constraint to the outer limit, and so may form the boundary of a Coastal State. Article 76 goes so far as to define the "the 2,500 metre isobath, which is a line connecting the depth of 2,500 metres." At the time that UNCLOS was drafted, and for most of the oceans today, the 2500 m contour was produced in the main from single beam echo-sounding data collected along individual, often randomly-oriented, tracks. Monahan [2000] reviews how most existing ocean maps showing the 2500 m contour were produced. Hughes Clark [2000] gives a comprehensive explanation of producing a 2500 m contour using MBES, but unfortunately not much of the world ocean is covered yet by this type of data. Table 6.1 summarises the material in both papers.

The next section examines the measurements that support the determination of the 2500 m contour and the uncertainty associated with them.

Table 5.1. Factors which contribute to the fidelity with which contours reproduce the sea floor.
[from Monahan and Wells,1999]

ELEMENTS THAT CONTRIBUTE TO THE UNCERTAINTY OF A DEPTH CONTOUR	
A. Factors that add to the uncertainties associated with a single sounding	
Depth measurement	Sound speed variations Beam width Constant errors
Positioning	Of survey platform Of seafloor sensed by instrument
Datums	Vertical or tidal datum Geodetic datum
B Factors that effect soundings collected along a track or profile	
Depth measurement	Masking of short wavelength features due to beam width effect Smoothing of the seafloor
Positioning	Position of the survey platform at fixes and between fixes
Sounding selection	Distance between soundings selected along track Selection at even intervals introduces wavelengths
C Factors that effect the fitting of contours to sounding data	
Arrangement of soundings	Density of soundings Pattern of tracks, including crossovers Orientation of tracks to seafloor features
Seafloor physiography	Simplicity or complexity
Method of contouring	Methods of surface fitting Honouring Data Size of the grid cells if gridding used
Complementary information	eg bottom composition eg sidescan eg predicted (satellite) bathymetry
D Complications particular to legacy data (collections of older data)	
Compilation errors or blunders. Non-availability of original echograms Scale and accuracies of hand plotted data Biases in sounding selection Accuracies of older instruments	

5.1 Deep echo-sounding and the production of the 2500 m contour

Extracted from:

Monahan, Dave (2001).

5.1.1 Introduction

To prevent Continental Shelves from becoming overly wide, two outer "constraints" are provided in Paragraph 5

> The fixed points comprising the line of the outer limits of the continental shelf on the sea-bed, … either … or shall not exceed 100 nautical miles from the 2,500 metre isobath, which is a line connecting the depth of 2,500 metres.

This gives hydrographers a once-in-a-lifetime chance to have their efforts establish the boundary of their country. In Canada, this will likely be the case offshore Labrador and in the Arctic Ocean. From work done to date, it can be predicted that the 2500 m contour will be used to establish the outer constraint in the Atlantic area east of Flemish Cap as shown in Figure 3.1.2. As always, the situation in the Arctic is more complicated, but it appears that Russia, at least, plans on using the 2500 m contour all the way to the centre of the Arctic Ocean, where their Continental Shelf will abut ours. [In fact, Russia so claimed after this paper was published. See United Nations, 2001]. As part of determining the 2500 m contour, the uncertainty in location of the 2500 m contour should be determined, As an illustration of its significance, the 2500m contour off Eastern Canada likely to be used is about 1200 nautical miles long. An error in its location of one nautical mile thereby generates a portion of the earth 1200 sq nautical miles or 4115 sq km in size that may be incorrectly assigned either to Canada or to the UN, (PEI is 5660 sq km)

5.1.2. Errors and uncertainty

All measurements have some error associated with them, and depth measurements are no exception. The errors in depth are grouped into two general types, fixed and variable. Fixed errors are those that are the same no matter how deep the water may be. For example, if the tidal datum is determined incorrectly, the error introduced will be fixed at a constant value independent of water depth. Every sounding taken will include that same error. Variable errors, on the other hand, are different for every sounding, growing larger with increasing water depths. The uncertainty of every sounding then, comes from a combination of its fixed and variable errors. How do they combine?

The Standards for Hydrographic Surveys, Special Publication 44 (S-44) of the IHO (International Hydrographic Organization, 1998a) provides a valuable framework for examining the uncertainty of a single depth. It provides the general case in which total error estimates are calculated as the RSS of the constant errors plus the errors that vary with depth, at the depth in question. In symbols this looks like

S = ± (a squared + (bd) squared)

Where

a = the sum of all fixed errors
bd = the sum of all variable errors
b = factor of variable error
d = depth
with a 95 per cent confidence interval [IHO, 1998].

It is worth spending a little time on this equation. Why aren't the two numbers simply added? Well, an error or uncertainty is not an absolute number in the sense of being a finite distance along the number line. When an error to any measurement, e.g. a sounding, is given, it represents the maximum value that the error is likely to take, 19 times out of 20 (i.e. 95% confidence level). Once out of 20 times, the error can exceed that value, but most of the time it will be less. Errors, at least for "cleaned" data, are more likely to be small than large, and usually follow the bell-shaped or Gaussian distribution curve. When adding two errors from different sources, it is extremely unlikely that both will be at the maximum value, since it is unlikely that either one will be at the maximum, and so it would be unreasonable to add the two maxima as if they were simple numbers. It has been determined that squaring each number, adding the results (i.e. the squares) and taking the square root of the sum, produces a number that conforms to the way that Gaussian errors combine. This is called the 'root sum of squares" in jargon. The result will always be less than a straight addition of the two errors, which makes sense, since the combined error must be more than the individual errors, but less than the two combined. Another aspect of the equation: as one number becomes larger than another, the combined error comes closer and closer to being that of the larger number. If one number is 10 times the other, the smaller adds less than 0.5% to the total error, and can usually be ignored: if one number is 100 times the other, the smaller adds less than 0.01%, and is normally considered noise.

S-44 is a standard to be attained, of course, not a means of measuring after a survey what uncertainty the survey actually achieved. It recognises that different parts of the seafloor are of different importance, and breaks surveys into four classes, or Orders, depending on the likely use of the area by surface navigation. For each Order, it specifies the maximum value that “a”, the sum of all fixed errors in the equation above can take, and “b”, the factor that is multiplied by depth to determine the variable error. As can be seen from Table 5.2.1, Line 1, the most rigorous of these, Special Order, calls for a maximum fixed error of 0.25 m, and a variable factor of 0.0075 [“b” in equation above], while the loosest, Order 3 has values of 1 m and 0.023 respectively. From these, values for the uncertainty at 25 m and 2500 m are easily calculated, Line 2. It is valuable to determine at which depths the two types of error would be equal [if the actual errors conformed to the constant values given in S44], Line 3: surveys at less than these depths will be dominated by fixed errors, at greater depths the variable errors take over and continue their rapid growth.

5.1.3. Why Do We Care – Horizontal Displacement Caused by Errors in Depth Measurement

All measurements have errors. This is a well-known fact. Why belabour it? We are concerned because errors in depth measurement translate into horizontal uncertainty in the location of contours (and the 2500 m contour will contribute to the outer limit of Canada, a horizontal line). The simplest way to visualise these uncertainties comes from examining the geometry of a single horizontal depth measurement over a sloping sea floor. Geometrically, this type of depth measurement is a straight line perpendicular to a horizontal line, the sea surface, and a sloping line, the sea floor, with variables being the slope of the seafloor and the uncertainty in depth measurement. In Figure 5.2,1 the distance AB between the sea surface and sea floor is exactly 2500 m, locating the 2500 m contour at B. The uncertainty in AB, (delta d) means that the contour will be displaced landward or seaward by a distance that is a function of the bottom gradient and the difference between 2500 m and the true depth. (Horizontal displacement = uncertainty in depth measurement / cosine of bottom gradient).

Table 5.1.1. S-44 elements.

Fixed error and variable factor come from S-44. Uncertainties at 25m and 2500m are calculated from these values, as is the depth at which the fixed and variable errors are equal. Text refers to line number (#). [Although values have been calculated in the shaded areas, the wording of S44 suggests that only Order 3 applies at 2500 m].

#	ELEMENTS		S-44 ORDER				S-44 ORDER			
			Special	1	2	3	Special	1	2	3
			Depth Accuracy				Bathymetric Model			
1.a	Fixed Error		0.25m	0.5m	1m	1m		1m	2m	5m
1.b	Variable factor	x depth	0.0075	0.013	0.023	0.023		0.026	0.05	0.05
2.a	Vert. Uncertainty at	25 m	0.31	0.6	1.15	1.15	0.31	1.19	2.36	5.15
2.b	Vert. Uncertainty at	2500 m	18.75	32.5	57.5	57.5	18.75	65	125.1	125.1
3	Depth at which fixed = variable	error	33	38	43	43	33	38	40	100
4.a	Horizontal Uncertainty	25 m								
	Bottom Slope	1 deg	18	34	66	66		68	135	295
		2.5 deg	7	14	26	26		27	54	118
		7.6 deg	2	5	9	9		9	18	39
4.b	Horizontal Uncertainty	2500 m								
	Bottom Slope	1 deg	1074	1862	3295	3295	1074	3724	7167	7167
		2.5 deg	429	744	1317	1317	429	1489	2865	2865
		7.6 deg	141	244	431	431	141	487	938	938

What bottom gradients can be expected? The 2500 m contours that will be used as part of a Continental Shelf submission will lie on seafloors that generally have gentle gradients, the Continental Slope and Continental Rise. As students, we were all shown simplified cross-sectional diagrams of the Continental Margin, which (despite their enormous Vertical Exaggeration) showed that the average gradient over the Continental Slope was in the order of 2 to 4 degrees. Pratson and Haxby [1996] probably began the modern era of measuring Continental Slope gradients when they compared both regional and local slopes as measured by MBES over five portions of the US Continental Slope. Not only were they able to measure gradient locally and regionally, they were able to relate them to lithology and tectonic history. The steepest area they examined was off New Jersey where they measured a regional slope of 2.5 degrees and a local slope of 7.6 degrees. Monahan and Mayer [1999] processed the same data and produced colour-intensity slope maps demonstrating that the locally steepest areas were on the canyon walls and that the lower gradients occurred down-slope from the canyons. These observations seem to confirm the 2 to 4 degrees average gradient expected.

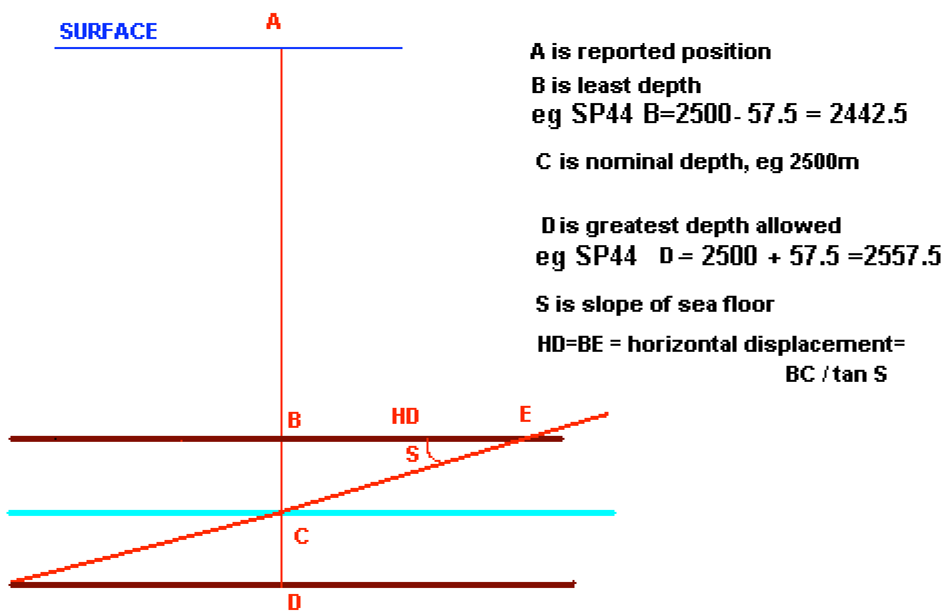

Figure 5.1.1 Geometry of horizontal displacement caused by uncertainties in measuring 2500 m.
(after Monahan and Wells, 1999)

We now have two components of contours, measurements and a sea floor. Since Article 76 defines the 2500 m contour as " a line connecting the depth of 2,500 metres", we must discuss the uncertainty associated with contour lines. The preparation of deep-sea contours from single-beam sounders has been described by Monahan [2000] while Hughes Clarke [2000] has elaborated the application of MBES in the deep ocean, and the means of extracting contour-like lines from it. As a general rule, the uncertainties created in the measurements by fixed and variable errors are not improved during the subsequent expansion from measurements to contours.

Submissions claiming a Continental Shelf must be tendered to the UN Commission on the Limits of the Continental Shelf (CLCS). That body has issued *Guidelines* [United Nations, 1999] that state that IHO S-44 will be used as the standard for bathymetric uncertainty. S44 appears to offer error magnitudes for contours, as well as for surveys, if Johnson's [1997] interpretation of the phrase "bathymetric model" as values interpolated from actual soundings is correct. If contours are streams or strings of interpolated values, then S-44 includes values for the fixed and variable errors, that are naturally and correctly relaxed from those demanded of individual soundings [Monahan and Casey, 1983]. Table 5.2.1, Line 4, shows the horizontal uncertainties allowed for each of S-44's Orders at 25 m and 2500 m water depths, for sea floors with gradients of 1, the maximum regional gradient of 2.5 degrees and the maximum observed 7.6 degrees, for both measurements and contours. It is possible that part of the boundary of a country could be determined with these horizontal uncertainties, although once approved, the line becomes fixed in law and loses all its uncertainty.

As hydrographers, we have to ask first if we can achieve these uncertainties, and secondly if we can exceed them. To do so, we examine the errors that occur in the real world.

5.1.4. Components of Fixed and Variable Errors

5.1.4.1 Fixed Errors

Since this paper is concerned with 2500 m depths, and, has been shown above, fixed errors are negligible at these depths, it suffices here to refer to Hare's definitive work on errors [Hare, 1997] which contains detailed analyses of fixed errors at navigation depths.

5.1.4.2 Variable Errors

The principal components of variable error are sound speed and beam width.

5.1.4.2.1 The effect of sound speed

Echo sounders measure the time between transmitting and receiving an echo, and they calculate depth by dividing the time in half and multiplying it by the speed of sound. Clearly, how accurately we know the speed of sound will affect the accuracy of the depth measurement. In shallow water, standard practice is to either perform a bar check periodically, which avoids having to determine the actual speed, or determine sound speed in the water with an instrument called a velocimeter, from which soundings are corrected to true depths using the velocities it measured.

[As an alternative to measuring velocity directly with the velocimeter] we measure salinity and temperature [and calculate velocity from them]. Generally, these can vary widely in shallow water, which includes rivers, estuaries, near-shore zones and the upper layer of off-shore water that is effected by surface winds, waves and currents. Deep water [below the shallow water defined in the previous sentence], on the other hand, has salinities and temperatures that are much more stable, with little vertical or horizontal variation.

Some [simplified] examples: suppose that an inshore survey in true depths of 25 m has calibrated its echosounder to show 25m in water which has a salinity of 35‰, at a temperature of 13 degrees C. Suppose the survey crosses an area where a river enters the sea and the salinity drops to 10‰: the echosounder will now show a depth of less than 24.5 *metre*s (enough to degrade the survey from S-44 Special Order to S-44 Order 1). Old-time hydrographers might think that at least the depth is shallower and therefor safer, but if the salinity had stayed the same and the water temperature increased by one degree, then the depth recorded would have been deeper than 25m. Of course, under such circumstances salinity and temperature usually both change, and can do so over quite short distances. Hughes Clarke et al. [2000] measured both parameters continuously over Georges Bank and concluded "the water column was varying significantly over length scales of as small as a few 100 metres" and should ideally be continuously monitored.

Now consider deep water, 2500 m in particular, and apply similar reasoning as above. Assume that the echosounder has been set to a fixed speed of 1500m/s, the true depth is 2500 m, the water has a salinity of 35‰, and a temperature of 2 degrees C. (a typical temperature in Atlantic Canada). If the salinity drops to 34‰, or if we mistakenly measure it as such, depth shown becomes

2499m, while if salinity rises to 35‰, depth shown is 2503m, not much to worry about. If the temperature rises by one degree, the depth shown becomes 2508, not a large uncertainty in depth measurement, but one which would create a horizontal uncertainty of ± 478 above a 1 degree sea floor gradient! These examples show that even small changes in salinity and temperature, or small errors in detecting them, can lead to fairly extensive horizontal uncertainty. How realistic are these magnitudes? Well, for most deep ocean areas, they are quite reasonable. However, the Continental Slope east of Newfoundland is an area where ocean currents converge to form what oceanographers call an Intense Frontal Zone, an area in which the water column is far more mixed than normal at these depths. Carter [1980], in the standard tables for sound speed correction, warns that errors of plus or minus 10 metres per second are to be expected in tabulated speed corrections for these zones. The Slope south-east of the Grand Banks lies in three different areas for which Carter's provides the following corrected depths: an echosounder set at 1500m/s over a true depth of 2500 m would report depths of 2489 (Area 9), 2476 (Area 12) and 2498 (Area 15), showing the range of uncertainty likely due to physical conditions. While these are all within the S-44 requirement of ± 57.5 m, how well we determine sound speed will effect the uncertainty in the boundary of Canada.

5.1.4.2.2 The effect of beam width

The discussion of sound speed deliberately oversimplifies the sound in the water as if it were a single ray, to make the geometry easier. Although this is useful, it is not what happens to real sound in real water. In the sea, sound emitted propagates away from the face of the transducer in a pattern that expands and resembles a lighthouse beam on a dark night. To describe the beam in something that can be handled with fairly simple arithmetic, and to reflect the fact that usually it is the strongest central part of the beam that does most of the work, sonar design engineers use the concept of "beam width" to rate sounders. Beam width is twice the angle between a line perpendicular to the centre of the transducer face [the boresight] and the point where the energy contained in the beam is reduced to half that at the perpendicular. Of course, there is energy outside the beam [as thus defined], and everyone reading this has seen returns from it on occasion, but most of the energy put out, and consequently most of the returned energy, (and more important, the first returned energy) comes from inside the beam width.

Table 5.1.2. Vertical errors and horizontal uncertainty introduced by sound speed errors of 0.1%, 10m/s and 1% .
10m/s comes from Carter's [1980] caution that errors of this magnitude can be expected in areas of significant water mixing, as to the east of the Grand Banks.

Sound Speed Var'n	Sound Speed error	Vertical Error	Percent of Depth	Horizontal uncertainty on seafloors sloping		
				1 deg	2.5deg	7.6 deg
m/s	m/s	m	%	m	m	m
1.5	2.50	2.50	0.10	143	57	19
10	16.67	16.67	0.67	955	379	125
15	25.00	25.00	1.00	1433	568	188

Figure 5.1.2 is a diagram of the propagating sound wave as it radiates away from the transducer face and occupies an area that becomes increasingly larger with depth. As the advancing wave front sequentially encounters the bottom everywhere within the ensonified area, some of its energy is reflected back. Over smooth bottoms, most of the energy makes it back to the transducer, but on rougher bottoms some returning energy will run into interference and either not make it back to the surface, or will arrive there late. Older echosounders record the energy that travels the shortest two-way distance as the 'first arrival' or 'first return' and this will be the depth reported, while more modern echosounders examine the entire returned signal and calculate some point within it as depth.

Beam width produces three different uncertainties. It can smooth the shape of large features and it can obscure features whose wavelengths are less than twice the ensonified area and it can introduce horizontal displacement when the seafloor is sloping. The reasoning behind the latter is the same as that explained in Section 5.1.3 and Figure 5.1.2. Some typical values are shown in Table 5.1.3. Thirty degrees represents the typical beam width of echosounders in common use for 2500 m depths until quite recently, and much of the legacy data over continental slopes will have been collected by equipment with approximately this beam width. At the other end of the spectrum, 2 degrees (or less) is typical for modern MBES systems. Note that a beam width of 24.6

degrees produces an uncertainty equal to the total uncertainty allowed by S-44.

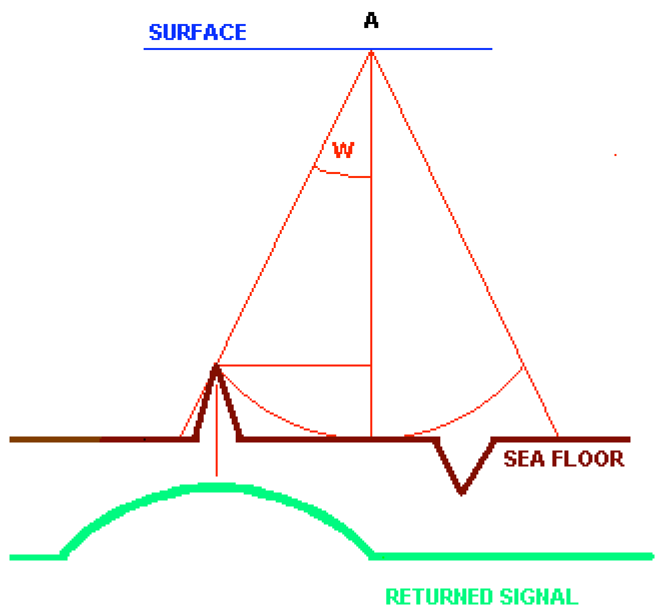

Figure 5.1.2 The smoothing and obscuring effects of beam width.

"Surface" is the sea surface over which the survey vessel (currently at A) moves from left to right or right to left. "W" is half beam width. "Seafloor" shows idealized elevation and depression. "Returned Signal" shows trace that would be returned by a beam of 2 x W. Elevation is smoothed and broadened, depression is obscured. (modified after Monahan and Wells, 1999)

5.1.4.3 Summary of [maximum possible] uncertainties in a single measurement

Sound speed and beam width uncertainties combine as RSS to form the total variable error. Variable errors also come from other elements, for example the fact that in 2500 m of water the transducer has moved for more than three seconds before receiving an echo from a sound wave it emitted, but these errors are normally small. (or else we don't know how to deal with them). Table 5.1.4 shows some values achievable with MBES (2 degrees), an arbitrary number that just meets S-44, and a 30-degree beam width typical of most of the SBES data that currently exists over the

Continental Slope. Since the later do not meet S-44, it seems that the CLCS is demanding that new data be collected as part of a submission.

Table 5.1.3. Magnitudes of horizontal displacement over seafloors sloping 1, 2.5 and 7.6 degrees caused by beam width at 2500m depth.

Nominal beam angle	Beam angle effect	Sound Speed Var'n	Sound Speed error	Vertical Error	Percent of Depth	Horizontal displacement on seafloors sloping		
						1 deg	2.5deg	7.6 deg
degrees	m	m/s	m/s	m	%	m	m	m
2	0.38	0.0	0.00	0.38	0.02	22	9	3
24.6	57.39	0	0.00	57.39	2.30	3289	1304	431
30	85.19	0	0.00	85.19	3.41	4882	1936	640

Table 5.1.4. Typical combined magnitudes of horizontal displacement over seafloors sloping 1, 2.5 and 7.6 degrees caused by beam width and sound speed variations.

Nominal beam angle	Beam angle effect	Sound Speed Var'n	Sound Speed error	Vertical Error	Percent of Depth	Horizontal displacement on seafloors sloping		
						1 deg	2.5deg	7.6 deg
degrees	m	m/s	m/s	m	%	m	m	m
2	0.38	1.5	2.50	2.53	0.10	145	57	19
24	54.63	10	16.67	57.12	2.28	3273	1298	429
30	85.19	15	25.00	88.78	3.55	5088	2018	668

5.1.4.4 Combining fixed and variable errors

S44's formula (Section 2 above) instructs us to combine the two types of error as RSS. However, since it also gives a maximum [allowable] value for the fixed error of ±1 m, and since the [maximum allowable] variable error at 2500 m is ±57.5 m, the fixed error is negligible. In fact, at the maximum, the fixed error would have to grow all the way to 12 m before the total error grew to 57.6!

The situation changes somewhat as the variable error becomes smaller, even approaching the fixed error as it might on the first line of Table 5.1.4. Since these numbers are within reach of MBES, Table 5.1.4 is repeated as Table 5.1..5 with the maximum allowed fixed error. It is clear that fixed errors make no difference at large beam angles, and when sound speed is poorly known, but can become important at MBES-like values.

Table 5.1.5. Values of horizontal displacement shown in Table 5.1.4 with the addition of the maximum allowed fixed error of ± 1m.

Fixed errors	Nominal beam angle	Beam angle effect	Sound Speed Var'n	Sound Speed error	Vertical Error	Percent of Depth	Horizontal displacement on seafloors sloping		
							1 deg	2.5 deg	7.6 deg
m	degrees	m	m/s	m/s	m	%	m	m	m
1	2	0.38	1.5	2.50	2.72	0.11	156	62	20
1	24	54.63	10	16.67	57.13	2.29	3274	1298	430
1	30	85.19	15	25.00	88.78	3.55	5088	2018	668

5.1 5. How can the values specified in S44 be attained?

It is one thing to produce a standard, it is sometimes a different thing entirely to achieve that standard. Armed with the analysis of variable errors above, we can examine some of the constraints on sounders and how they relate to the standard.

Consider first the errors introduced by beam width. To achieve the total error allowed under S44, there are maximum beam widths beyond which the geometry of the beam dictates that the standard cannot be met. If the sound speed is perfectly known, then in 25 m depth Spec Order requires a beam width of 13.6 degrees or less, Order one requires a beam width of 18.8 degrees or less, while Orders 2 and 3 require 24.6 degrees or less (as Order 3 will in 2500 m of water). Now, imagine that beam width is not a factor, and that only a variation in sound speed will produce the variable error, an impossible situation of course, but an illustrative one. An error in sound speed of 1.25% would cause a sounding to exceed the limits of Spec Order at 25 m, as would an error of 2.38% for Order One. Order 2 an 3 would be exceeded at 4.6% at 25 m, while at 2500 m Order 3 would be exceeded at 2.3%, a number familiar from S-44, since the fixed error of ±1 m would contribute virtually nothing at this depth. In reality, both sound speed and beam width contribute, so that sound speed would have to be known to much better levels than this.

The planning task for any survey will have to [be] expanded to deal with this. If the planner is reasonably sure that sound speed can be measured to a certain uncertainty, then the maximum beam width can be calculated. Conversely, if the sounder is not alterable, the uncertainty to which sound speed must be measured can be calculated.

5.1.6. Possible improvements through the use of multibeam data.

Most of the continental Slopes of the world are covered by legacy data, primarily individual tracks, collected over many years. Very little of it is MBES. Coastal States may be wish to conduct multibeam echo sounding (MBES) surveys for UNCLOS purposes, and this paper has shown that in terms of uncertainty, this offers certain advantages.

The use of MBES in continental shelf delineation has been described extensively by Hughes Clarke [2000] who concludes that MBES can “markedly improve the exact location of the 2500 m contour” and that “local absolute maximum protrusions of this discrete contour line can be identified”.

These conclusions were tested for an area off New Jersey, USA, by Monahan and Mayer [1999] who combined contours derived from ETOPO5, the Predicted (Satellite) Bathymetry from NOAA, the GEBCO contours and the 2500 m contour from a multibeam survey undertaken for the USGS. They measured the horizontal distances between the contours and found that they occupied a corridor approximately 10 km wide, a value that corresponds well with the horizontal uncertainties shown in Table 5.2.1. The MBES- derived contour wove itself through this zone of uncertainty, occasionally, perhaps 5% of the time, “protruding” landward or seaward from the zone. These could contribute to the outer limits by producing a 2500 m contour (from which 100 nautical miles will be measured) that could be hundreds of metres to several kilometres seawards from the contours that conform to S-44.

5.2 Isolated Elevations

Paragraph 6 of Article 76 acknowledges that submarine elevations can be "natural components of the continental margin". Monahan and Wells [1999] draw attention to the fact that there

> are the many areas where 2500 m contours surround "submarine elevations" that are morphologically isolated from the contiguous continental slope yet may be close enough to a Coastal State to form part of the "natural prolongation of it's land territory". Demonstrating that such elevations are part of an Extended Continental Shelf will require investigation of their geological origin.

They go on to point out that if an isolated elevation is part of a Continental Shelf, then in cases where the 2500 m contour plus 100 nautical miles line is used, decisions will have to be made about which 2500 m contour the 100 nautical miles is measured seaward from.

Extracted from:

Monahan, David and D E Wells, 2001.

> At a gross scale, in areas of complex seafloor morphology, uncertainty arises from trying to decide which sections of the 2500 m contour to use. There are many areas where 2500 m contours surround "submarine elevations" that are morphologically isolated from the contiguous Continental Slope, yet are close enough to it that a Coastal State is justified in claiming that the elevation forms part of the "natural prolongation' of the land territory. If this can be established, then presumably the 100 seawards is measured from the 2500 m contours that fringe the isolated submarine elevations. The sketch map in Figure 3.1.2 illustrates a case in Canadian waters. Orphan Knoll is a seafloor elevation surrounded by a 2500 m contour. As can be seen, the area that may or may not lie on the Canadian Continental Shelf, depending on whether Orphan Knoll can be used, is of considerable size.

There are also areas where the 2500 m contour doubles back on itself parallel to the Continental Slope, and Coastal States will attempt to show that the outermost section of contour should be used. It is evident from the *Guidelines* [United Nations, 1999] Paragraph 4.4.2, that this will not be accepted automatically by the CLCS, and that the Coastal State will have to demonstrate why the closest landward section should not be used.

Uncertainty introduced by questioning whether or not a feature can be used, or which meander of a contour is the critical one, is considerably greater than any introduced through measurement errors. However, we are not very comfortable with them, since they cannot be quantified. We recognize their importance and the major impact they can have.

As the scale of investigation is enlarged, roughness caused by the presence of smaller features than isolated elevations manifests itself through increased sinuosity of the 2500 m contour (assuming there is sufficient data to support the new scale). With increasing scale, smaller and smaller physical features manifest themselves as convolutions in the contour. One challenge is to find a scale appropriate to displaying the 2500 m contour adequately. The framers of Article 76 may have given some guidance since they specify in Paragraph 7

"The Coastal State shall delineate the outer limits of its continental shelf …by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by co-ordinates of latitude and longitude."

Although the outer limit will be smoother than the 2500 m contour, any line defined at point 60 nm apart is not very sinuous, and can be portrayed at a small scale. on the other hand, a Coastal State seeking the maximum seaward extent of it Continental Shelf will want to select the fixed points carefully, and will probably want to conduct a large scale search to determine which are the most seaward. "Large-scale" in this context means MBES and the use of MBES in 2500 m contour delineation has been described extensively by Hughes Clarke [2000] who concludes that "local absolute maximum protrusions of this discrete contour line can be identified".

[Monahan and Wells, 2001.]

5.3 Summary

The 2500 m isobath plus 100 nautical miles is one of the possible constraints to the Outer Limit. Article 76 defines the 2,500 m isobath as "a line connecting the depth of 2,500 metres." For most of the ocean, the 2500 m contour has not been mapped in detail, yet arcs 100 nm in length swung from it may become the boundary of a Coastal State.

Water depths are measured by echo sounding, which is a vertical measurement from the sea surface to the seabed. Uncertainty in the vertical measurement will translate into horizontal uncertainty through division by the tan of the slope of the seafloor. Since seafloor slopes at 2500 m are generally small (less than 4 degrees), horizontal uncertainty can be quite large (in the range of ± 7 km).

CLCS *Guidelines* specify the use of the IHO Standard for Hydrographic Surveys, S44. Applying that standard determines how large the horizontal uncertainty can be while satisfying the CLCS.

S44 separates fixed and variable errors and gives a formula for combining them. At 2500 m, the contribution of fixed errors is negligible for SBES, but can be significant for MBES surveys. Variable errors can be large at 2500 m, but those allowed in the standard are greater than they need to be with modern echo sounders and sound velocity determination methods. MBES surveys produce a much more detailed contour, one that generally lies within the zone of uncertainty of the SBES – derived contours, occasionally falling landward or seaward from the zone. Careful selection of the most seaward of these as point from which 100 nautical miles can be measured could lead to a larger Continental Shelf for a Coastal State.

Not all 2500 m contours lie on simple, planar Continental Slopes. There are areas with off-lying “submarine elevations” surrounded by 2500 m isobaths that may or may not form part of the “natural prolongation” of a Coastal State. Uncertainty introduced by questioning whether or not a feature can be used is considerably greater than any introduced through measurement errors.

CHAPTER 6
DEFINE THE BASIS FOR GOING BEYOND 200 NAUTICAL MILES

Having established the zone within which a Continental Shelf may lie, the Coastal State must next "Define the basis for going beyond 200 nautical miles". Section 3.1.2.4 begins the discussion of this key element and points out that to establish the Outer Limit within the zone possible, a state must either establish the location of the Foot of the Slope or prove that it does not exist as a physiographic feature and use the "*evidence to the contrary"* clause. This chapter describes mapping the Foot of the Slope.

6.1 Mapping the Foot of the Slope according to Article 76

Extracted from:

Carleton, Chris M, Steve Shipman, David Monahan, and Lindsay Parson. (2000).

> It is useful to retrace the history of the development of Article 76 to help understand what the framers were trying to achieve and therefore what interpreters must try to provide. This can facilitate our understanding of how to interpret the sometimes-obscure concept of foot of the slope.
>
> In the early 1970s, the concept that the continental margin was a "prolongation of the landmass" was accepted. It was recognized that the oceanic crust was fundamentally different from that underlying the continents and that States were entitled to claim the continental portion. The question then became one of defining the continental margin in a way acceptable to the international community. At that time, a large amount of what was known and

published about margins was dominated by Wood's Hole Oceanographic Institution and Lamont Doherty Geophysical Observatory. Their close physical proximity to what is now known to be a passive margin, led to the production of many cross-sectional diagrams showing a horizontal continental shelf terminating at its seaward extent at an abrupt shelf break. Following the break, the diagrams usually showed a slope descending at 30-45 degrees, to a point where they joined the rise, which was shown sloping at about 15 degrees downward to the abyssal plain, which was shown as flat. The vertical exaggeration in these diagrams was enormous (the slope usually has a gradient of 1-3 degrees, while that of the rise is less than one degree) and may have created an early impression in some framers' minds that (i) all continental margins were of this type; (ii) the transitions from one zone to another were clearly delineated; and (iii) therefore, it would be relatively simple to map any of the features shown.

None of these is true. Among the many people involved in LOS formulation who recognized the complexity of the margin, Hedberg of the United States suggested that a boundary zone of agreed-on width be used to capture the interface between ocean and continent. Gardiner of Ireland was concerned that this might not capture all the continental material and suggested a modification wherein sediment thickness, a natural phenomenon rather than an arbitrary measurement, was included as a determining factor [Gardiner, 1978]. To allay fears that difficulties in determining the foot of the slope might lead to too great an area being claimed, the 2500-m-plus-100-nm and 350-nm clauses were also introduced.

In principle, the foot of the slope represents an attempt to separate continent and ocean. It has a similar importance in defining the limits of the continental margin, just as the territorial sea baseline has in defining the seaward limit of other maritime zones within UNCLOS. It is in effect the continental shelf baseline. Turning this principle into a line on a map requires a major effort in interpretation and analysis by States that have to rely on the foot of the slope for establishing claims beyond 200 nm. In article 76, it is the foot of the slope that determines the outer limit based on distance (article 76.4(a)(ii), the "Hedberg line"), and it forms the baseline from which the sedimentary thickness is measured (article 76.4(a)(i), the "Gardiner line").

6.1.1 Mapping the Foot of the Slope

There is a saying among seafarers that "the hardest part about captaining a ship is finding a ship to captain". It may be that among article 76 claimants, the hardest part about mapping the foot of the slope is finding a foot of the slope to map! What exactly is the foot of the slope? Paragraph 4(b) of article 76 defines it this way: "In the absence of evidence to the contrary, the *foot of the continental slope* shall be determined as the point of maximum change in the gradient at its base". Note that there is no quantification of the gradients involved; all that is required is to find the point where the gradients change the most. Nor is there any specific depth associated with the foot of the slope, although article 76 does give some guidance in that it uses the word *base,* meaning toward the deeper part of the slope. "Evidence to the contrary" is not defined, but it appears that other arguments may be entertained that can overrule the morphometric gradient determinations. Since we are looking for the edge of the continent, evidence for this most likely would come from seismic work, particularly where structural boundaries mark the edge of continental crust. Clearly, there is no "exact" foot of the slope; there is, rather, a zone in which judgment must be applied to determine the most likely location of the feature which is taken to mark the edge of the continent.

There may be some areas of the passive margins around the Atlantic where it is possible to find a well-defined transition from slope to rise. In such cases, it would be possible to draw a foot of the slope line by simply picking the point where the gradient changes on an echo-sounding profile. Elsewhere, the task will be much more difficult, but the following approach may help to detect and map the foot of the slope:

i. Determine the change in slope from contour maps and/or profiles derived from them.
ii. Select the candidate foot-of-the-slope points on profiles measured directly by echo-sounding and seismic profiling techniques.
iii. Produce slope maps from multibeam surveys.
iv. Use statistical techniques based on raw sounding data, on gridded data, or on contour maps.

Each will be discussed from a theoretical viewpoint. The section following gives an overview of a practical approach with examples.

6.1.1.1 Determining the Change in Slope from Contour Maps and/or Profiles Derived from Them

Contoured bathymetric maps are discussed at length in [Chapter 5 of this thesis]. They provide a layered or stepped view of the seafloor; a foot-of-the-slope line can be interpreted from them with varying degrees of accuracy. Gradient can be determined from contours by scaling the horizontal distance between them on the map and dividing that distance into the vertical distance depicted by the contour interval. On the same map, gradients are steeper where contours are closer together and less steep where contours are further apart, provided of course that the contour interval is the same. In theory, the foot of the slope may therefore be shown at the place where the closely spaced contours of the slope widen as they start to depict the rise or the abyssal plain. On some continental margins, it is possible to differentiate the more closely spaced contours on the slope from the slightly more widely spaced contours over the rise. It is also possible to construct profiles across contour maps, and to use them to help find or emphasize the foot of the slope.

The horizontal scale of bathymetric maps covering the slope and rise is usually quite small, with 1:200,000 or 1:250,000 being the best, and with 1:1,000,000 and smaller being more usual. This means that measurements between contour lines cannot be very accurate, since at 1: 1,000,000, the inked contour line itself represents a zone several hundred metres wide on the seafloor. There is no need to measure in the vertical direction, since the contour interval is determined by the mapmaker and, on the slope, is usually 100, 200, or 500 m. The different precision between horizontal and vertical dimensions is not too important, since we are seeking a relative change in slope, not an absolute one. What is important is that bathymetry maps can show the foot of the slope to some degree of precision and, perhaps more important, with some consistency.

Contoured bathymetry maps have the advantage of being readily available and are in widespread use for most continental margins. They exist as international series (e.g.,GEBCO), covering the margins of all nations, and are readily understood. What is difficult to establish is the continuity of the foot of the slope around a margin. If a bathymetry map shows the same or a similar picture of the foot of the slope over an area, without having to move up- or downslope too much, this is a good indication that the foot of the slope chosen is reasonable. Bathymetry maps may possibly be the best medium for depicting foot of the slope since they filter out many of the uncertainties inherent in other techniques. Their simplicity is their strength.

Nonetheless, bathymetric maps do have some disadvantages. The location of a foot-of-the-slope line is limited by the contour interval selected by the map's authors, in that it can only be located somewhere between two contours. Given that the true horizontal distance between contours can be miles or even 10s of miles, this may be judged to be too crude for LOS purposes. Also, bathymetry maps are not always of uniform quality throughout a map sheet, due to the distribution of the data on which they are based. They are also vulnerable to interpretive bias in their construction; consequently, the confidence that can be placed in them is variable. Finally, working with contour maps alone, it is possible to arrive at more than one interpretation of the foot of the slope.

6.1.1.2 Selection of Candidate Foot-of-the-Slope Points on Profiles Measured Directly by Echo-Sounding and Seismic Profiling Techniques

Echo sounders and seismic profilers produce a digital and/or analogue profile of the signals returned to them from the seafloor. Thus, they represent the most detailed cross section measured along the track followed by the ship. They can be examined by eye or by mathematical techniques to pick changes in slope, which may then be correlated from one profile to the next. Visual inspection of paper-trace echograms can be used to define all changes of slope that could reasonably be the location where the foot of the slope and the echo-sounding trace intersect. This is usually done in combination with examination of a bathymetric map of the area, to help ensure that the feature chosen is indeed reasonable. One echogram alone is clearly not sufficient to establish foot of slope, but if a similar feature occurs on adjoining echograms, then it is possible that the feature is continuous between them. Normally, a foot of the slope will not vary greatly in depth over short distances. Through visual inspection, one is trying to identify a point where the gentle gradient of the slope becomes even gentler. Candidate points are selected (and there may be more than one per echogram) and plotted onto a bathymetry map to help determine continuity between the possible points. Continuity does not guarantee that the points chosen represent the foot of the slope, but strong continuity is a good indicator of the validity of the pick.

It is possible to attempt essentially the same method for picking the foot of the slope using digital methods, if the echo trace has been digitized or if the echo sounder was a digital instrument. In this case, the slope is measured between adjacent points along the echogram, then compared with the slope between the two preceding points. This process is repeated along the parts of the profile in the appropriate area, and the pair of slopes exhibiting the greatest difference is chosen as the location of the foot of the slope. However, this method may be subject to another level of imprecision; while echograms can be considered continuous profiles, digitizing is a sampling of them at a fixed interval. If the spacing between the sample points is small, the effect is negligible, but if the sample points are kilometres apart, as they can be with older records, the resolution of this method is degraded.

Echograms have both horizontal and vertical scales, and since the two are rarely the same, they offer a degree of vertical exaggeration that can emphasize the changes in slope along their track. Digital records can be manipulated to further enhance this attribute. Within the echogram, there is a scale effect that varies with water depth. The sound pulse emitted by the echo sounder spreads out with increasing water depth. This spreading leads to an increasingly large footprint on the seafloor, meaning that larger and larger features are missed as depth increases. This will affect finding the foot of the slope in cases where it appears as a distinct feature. In particular, it may make a feature found on a narrow-beam sounder difficult to trace onto profiles measured with a wide-beam sounder.

The primary advantage of working with echograms, particularly in cases where the results may be in dispute, is that the echogram shows exactly what the instrument recorded, without having passed through any other sampling filters or being biased through interpretation.

Nonetheless, echo sounders do have some disadvantages, given that the foot of the slope is a subtle feature, representing a change of slope of three degrees or less. It is easiest to find such a change in a profile that runs directly downslope, perpendicular to the general slope, since any deviation from that line reduces the angles of slope portrayed on the profile. Unfortunately, since echograms may have been collected on a random pattern, or before the actual slope was known, they might not run perpendicular to the slope, thus weakening their power to capture the foot of the slope. If the slope were a continuous sloping plane, this effect would be of little consequence, but since the slope is usually rough and incised with canyons, the degradation of resolving power makes finding the foot of the slope more difficult. Furthermore, as mentioned under impact of scale, beam width may mask smaller subtle features.

6.1.1.3 Statistical Techniques Based on Raw Sounding Data, on Gridded Data, or on Contour Maps

It is possible to search for the foot of the slope within the data using mathematical or statistical techniques. The basic numerical value is the sounding, and it is possible to operate on a geographic array of soundings as they are collected. Except in the case of multibeam data, the spatial arrangement of actual soundings is often not conducive to numerical processing, and a regular grid of derived depth values is created. There are numerous ways of doing so, but essentially, what is done is as follows: At the first intersecting point of a regular grid a value is calculated based on the true soundings near that location and then recorded. The operation moves to the next grid intersection where the calculations are repeated, and so on until the grid is completely filled. Factors that go into the calculation of grid values include:

i. The number of real soundings to be included in each calculation;

ii. The contribution of distance from grid point to real soundings;

iii. The importance of isolation or clustering of real soundings; and

iv. The method of curve fitting to real soundings and candidate grid point.

Grids can also be constructed from contour maps, meaning that they are at least one step further removed from the original data. Consequently, the values of nearby contours, rather than soundings, contribute to the calculated grid.

Starting with such grids, a number of mathematical techniques can be used to estimate the position of the foot of the slope. Bennett [1998], for example, calculated the surface of the second derivative through each point and used the crests of the calculated surface to locate a maximum change of slope. Vanicek et al. [1994], used least squares to fit surfaces of various orders to sounding data. Since it is easy to fit surfaces to a grid, it should also be possible to start on either side of the suspected location of the foot of the slope and fit a surface to each side before extending the area covered by each surface toward the foot of the slope with the intersection of the two surfaces being taken to define the foot of the slope.

Scale manifests itself first through the distribution and density of the sounding data. Sounding spacing and layout will dictate at what scale each of these approaches replicates nature, but availability of data will not be under the control of the modeler. Selection of grid size based on those soundings is controllable but can pose difficulties: Constructing a grid that is too fine in relation to the sounding spacing does not produce a grid at a better scale. Grid size must be selected with care, based on what the data will support, and on minimizing the risk of aliasing (the introduction of false wavelengths). The scale of contour maps is given in the horizontal direction by the map's published scale and in the vertical direction by the contour interval. Statistical techniques usually apply only at the large scale. Their principal advantage is that they can be applied in instances where no other approach offers much chance of success, either because the data are sparse or because there is no discernible foot of the slope within the area being studied. The latter situation could arise because the bottom is too rough and contains a great number of breaks in slope or, paradoxically, because the seafloor is too smooth, making it difficult or impossible to say where the slope stops and the rise begins. But statistical techniques do not usually give exact results. Perhaps even more important, they do not give the impression of producing good results. This may make their acceptance by the CLCS problematic, despite the fact that they can be very powerful devices in situations where other methods have proved to be unsatisfactory.

6.1.1.4 The Production of Slope Maps from Multibeam Surveys

Multibeam surveying is described in [Hughes Clark, 2000]. The primary advantage of multibeam surveys is the complete coverage of the area that they provide. Within this coverage, there will be places where the foot of the slope is apparent. In other cases, it can be examined and followed using multibeam technology. This could ensure, first, that the identified feature is in fact a break in slope and, second, that it is continuous.

The main disadvantage of this type of data is that there is not yet extensive coverage available on a worldwide scale. Since they must be collected from a ship, multibeam data are expensive to collect and process. A deployment strategy of using one of the other techniques before multibeam can keep expenses down. Another possible disadvantage is that at times, the data may be too detailed or localized, rendering it difficult to find the foot of the slope, particularly in areas where it occurs over a zone, rather than as a definite individual feature. [Such cases, if they occur, are examples of the difficulty of applying a small-scale model, the Foot of the Slope, to a large scale map, the output from the MBES survey.]

6.1.2 The Procedure to Be Followed

i. Choose method(s) of determining foot of the slope.
ii. Prepare draft survey lines.
iii. Decide if data are sufficient.
iv. If not, decide where more are needed.
v. Run through the process again more carefully.

The 2500 m plus l00 nm line and the 350-nm-from-baselines line can be plotted on the same bathymetric map, producing a map of a zone whose inner limit is 200 nm and whose seaward limit is made up of the combination of the 2500 m plus 100 nm line and the 350 nm lines. There are three cases which then become possible:

i. The foot of the slope plus 60 nm is clearly inside the 200-nm line, in which case the sediment thickness approach may be applied or the maximum will be 200 nm.
ii. The foot of the slope plus 60 nm is between the 200-nm line and the maximum allowed, and therefore, the foot of the slope plus 60 nm must be developed.

iii. The foot of the slope plus 60 nm is clearly outside the maximum allowed, in which case the maximum will be the outer limit.

From the previous discussion, it is clear that when mapping the foot of the slope, no one method is superior, and the selection of which method to use depends on the physiography of the area being mapped, the types of data available, the human expertise and backup computer power available, and the time and funding available.

It is also apparent that in many cases, these approaches will not produce a foot of the slope which is a well-defined line but will produce a zone or area within which the criteria are met to varying degrees of certainty. The width of the zone of uncertainty will vary along the continental margin. To establish an outer limit requires picking points within this zone no more than 60 nm apart. Often, it will be possible to do this for points where the zone is very narrow or even just a line. Where this is not the case, the seaward extent of the zone of uncertainty can be selected.

Given these various conditions, the best approach is to apply as many as possible of the techniques described above. Then, compare the results, and use the combined results to refine the foot-of-slope line. Where real-world limitations of time and resources restrict the amount of work that can be done, working sequentially through the techniques outlined above, beginning with contoured bathymetric maps and working toward multibeam surveys, is the most realistic and resource-efficient way of proceeding.

This exercise will at times reveal that there is an absolute need to obtain more data before a credible foot-of-the-slope line can be drawn, either because no likely line is found or because several possibilities exist. In this latter case, obtaining appropriate data must be carefully planned since the sediment thickness measurement may also need more data; [combined] bathymetric and geophysical cruises are obviously cost-effective.

[Carleton, Shipman, Monahan, and Parson, 2000]

6.2 Mapping the Foot of the Slope according to the CLCS *Guidelines*

The paper quoted in Section 6.1 was, despite its publication date, written before the release of the CLCS *Guidelines* in 1999, and was consequently based on an interpretation of only Article 76. However, perhaps in an attempt to assist with the search for the elusive Foot of the Slope, perhaps to reduce the spatial range in which Foot of the Slope can lie, possibly to tie the Foot of the Slope to the division between continental and oceanic crust, Paragraph 5.1.2 of the *Guidelines* states that Article 76 Paragraph 4 (b) "provides a *dual* regime for the determination of the foot of the continental slope". The *Guidelines* assert that the phrase "the foot of the continental slope shall be determined as the point of maximum change in the gradient at its *base*" requires "The identification of the region defined as the *base* of the continental slope". (Emphasis added). In Paragraph 5.4.5,

> The Commission defines the base of the continental slope as a region where the lower part of the slope merges into the top of the continental rise, or into the top of the deep ocean floor where a continental rise does not exist.

Having defined the Base of the Slope, the CLCS then provides instruction on how it is to be delineated in Paragraph 5.2.1

> Bathymetric *and geological* data provide the evidence to be used in the geomorphological analysis conducted to identify the region defined as the base of the continental slope. (Emphasis added).

This seems to imply that *both* bathymetric *and* geological evidence must be supplied simultaneously, However, Paragraph 5.4.4 is permissive and allows the possibility of not using geology:

> Many continental margins, however, depart from this ideal picture, and in such cases geological and geophysical data *may* be used to assist in identifying the region referred to here as the base of the continental slope. (Emphasis added).

Finally, the *Guidelines* back away from demanding that both types of evidence be applied, with Paragraph 5.4.6

> As a general rule, whenever the base of the continental slope can be clearly determined on the basis of morphological and bathymetric evidence, the Commission recommends the application of that evidence. Geological and geophysical data can also be submitted by Coastal States to supplement proof that the base of the continental slope is found at that location.

The author interprets this to mean that within a submission, Coastal States will have to demonstrate that they have searched for a base, and in some cases finding one will be apparent from simply the surface expression of the sea floor (i.e. morphology and bathymetry). If it is, then the base so mapped can become the area in which the search for the Foot of the Slope is carried out. On the other hand, should these parameters not yield a base, then geology and geophysics may (have to) be invoked. It is not clear how geology and geophysics will be used to distinguish Slope from Rise: usually the two are sedimentary bodies differentiated only by their surface gradients. Some models have a Rise that is composed of unconsolidated sediments and a Slope that is generally consolidated; it may be possible to differentiate between these by using seismic or gravity methods. However, describing a Rise as unconsolidated would prevent the use of the sediment thickness formula which applies to ” sedimentary rocks”.

Introducing this new feature, the Base of the Slope, does not appear to simplify anything, and it remains to be seen whether it will be applied or ignored.

Where bathymetric data is to be used, the *Guidelines* insist that “Methods based on a purely visual perception of bathymetric data will not be accepted by the Commission.” The same paragraph points out

> The determination of the location of the point of maximum change in the gradient at the base of the continental slope will be conducted by means of the mathematical analyses of two-dimensional profiles, three-dimensional bathymetric models and preferably both.

What would a “mathematical analysis of a two-dimensional profile” consist of? In CARIS LOTS, and no doubt in other software, a function exists that will produce a continuous graph of the second derivative of the curve representing the sea floor: in theory, it peaks at the maximum change of slope. In practice, this approach produces multiple peaks, one of which must be selected (visually) as corresponding to the Foot of the Slope.

6.3 Evidence To The Contrary

The general rule for defining the Foot of the Slope is a morphological one, “the point of maximum change in the gradient at its base.” Exceptionally, the Foot of the Slope can be determined as something else, but the Convention does not specify what the something else is. In keeping with the intent of Article 76 to define the boundary between continent and ocean, it is generally believed that States can use geological arguments to establish a location where the two abut and treat that as the Foot of the Slope from which the Outer Limit can be measured.

The CLCS *Guidelines* address this as follows, Paragraph 6.3.1:

> Evidence to the contrary to the general rule in article 76, paragraph 4 (b), is interpreted by the Commission as a provision designed to allow Coastal States to use the best geological and geophysical evidence available to them to locate the foot of the continental slope at its base when the geomorphological evidence given by the maximum change in the gradient does not or can not locate reliably the foot of the continental slope.

The *Guidelines* go on to point out that if evidence to the contrary is used, claiming states have to:

i) Justify its use through exhausting the 'regular' path

ii) Provide evidence to show that regular path does not apply

iii) Develop the evidence to the contrary case.

6.4 Summary

The intent of the framers of UNCLOS in codifying the Foot of the Slope within Article 76 was to provide a means of dividing the seafloor based on whether the underlying rock was of continental or oceanic origin. In gross terms, they believed that a surface feature, the Foot of the Slope, could be used as a basis for making this determination. They provided a definition of the Foot of the Slope as a physiographic feature and allowed for the exceptional possibility that some portions of the seabed may not conform to this definition. The *Guidelines* insist that the alternative can only be used after it has been proved that the Foot of the Slope does not exist; consequently, an attempt must be made to determine the location of the Foot of the Slope.

Finding a portion of the real sea floor that fits a concept taken from a small-scale diagram, as the Foot of the Slope was, is not easy nor does it produce unambiguous results. Some cross-sections of continental margins show no "maximum change in gradient at its base", others show many. Several techniques have been mentioned but all leave abundant latitude for interpretation. The best approach is to apply as many as possible of the techniques described in this chapter, compare the results, and use combined results to refine the foot-of-slope line.

Methods for finding the Foot of the Slope can be based on raw sounding data (single beam or multi-beam), on gridded data, on profiles or on contour maps. The *Guidelines* rule out analysis by "purely visual perception" and insist that some form of mathematical device be used. Several surface fitting techniques have been proposed, as has determining the second derivative of both profile and surface data.

The CLCS *Guidelines* complicate the picture, while perhaps endeavoring to simplify it, by requiring that before a Foot of the Slope can be delineated, the region defined as the *base* of the continental slope must be identified. The author believes that this requirement will be ignored, since it is not supported by Article 76.

Finding the Foot of the Slope from bathymetric data using “visual perception” is not acceptable to the CLCS; only some undefined mathematical analysis is.

As an exception to the general rule for defining the Foot of the Slope as “the point of maximum change in the gradient at its base”, the Foot of the Slope can be determined using unspecified “evidence to the contrary.” It is generally believed that geological arguments can be used to establish the ocean/continent boundary and treat that as the Foot of the Slope line. The *Guidelines* insist that it must be proven that a morphological Foot of the Slope does not exist before this clause can be invoked.

CHAPTER 7
UNCERTAINTY IN LOCATING THE OUTER LIMIT OF A CONTINENTAL SHELF

The diplomatic and legal negotiators who framed UNCLOS can be justifiably proud that they have introduced a definition of the Continental Shelf that 138 states (as of 10th September 2002) have ratified. The definition assigns most of the continental rock to the Coastal State and at the same time constrains the amount of territory a state can claim so that a large area is left to the common heritage of mankind. It is up to scientists and engineers to delineate and demarcate the boundary. How well we do so may not matter for years to come, but once seabed exploitation commences near a Continental Shelf / Area juncture, the uncertainty in locating the boundary could become an important economic issue.

This chapter examines the uncertainty in the Outer Limit.

Extracted from

Monahan, Dave and Dave E Wells, 2002.

7.1 Comparative uncertainty between all components of a Continental Shelf claim

Article 76 says nothing directly about how accurately the 2500 m isobath, or indeed any of the other elements that it includes, needs to be located. However, an indirect indication may be embedded in Paragraph 7 which states

> "The Coastal State shall delineate the outer limits of its continental shelf, ... by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by co-ordinates of latitude and longitude."

Clearly the drafters of the Convention, who were defining the locus of the outer limit, were prepared to live with a boundary that could be delineated by straight line segments, joining points that could be up to 60 nm apart. They offer no guidance on how well the co-ordinates of latitude and longitude are to be delineated: traditional rule of thumb says that co-ordinates recorded to the nearest second are positioned to within ±30 m, but co-ordinates could be reported to the nearest minute, for instance, and still comply with the letter of the treaty. Was the treaty crafted this way in order to make it less expensive for a country to prepare a claim, perhaps? Perhaps flexibility was wanted, since Coastal States may delineate their outer limit by points very closely spaced if desired. In practice, a Coastal State seeking to maximise its Continental Shelf will use 60 nm segments where the limit is concave towards land and very short segments where it is convex away from land.

Do the 60 nm maximum line segments impact the uncertainty required of the 2500 m isobath and other components? Article 76 defines the final outer limit of the extended Continental Shelf of any Coastal State as a line that could be made up of a section that is 350 nm from the baselines, a section that is 100 nm from 2500 m contour and a section that is 60 nm from the Foot of the Slope, and a section based on sediment thickness from Foot of the Slope. The uncertainty associated with delineating this limit would vary from metres to tens of metres for the 350 nm section, tens of metres to hundreds of metres for the 2500 m contour, and hundreds of metres to tens of kilometres for the two criteria that begin with locating the Foot of the Slope. See Table 7.1.1 and Figure 7.1.1.

It could be argued that the required uncertainty of the outer limit is determined by the significant numbers in the co-ordinates of the points joining the straight lines. The uncertainty that the individual components must have in order to achieve this could be calculated. Alternatively, the uncertainty in the contributing components could be calculated and the outer points recorded to an equivalent uncertainty.

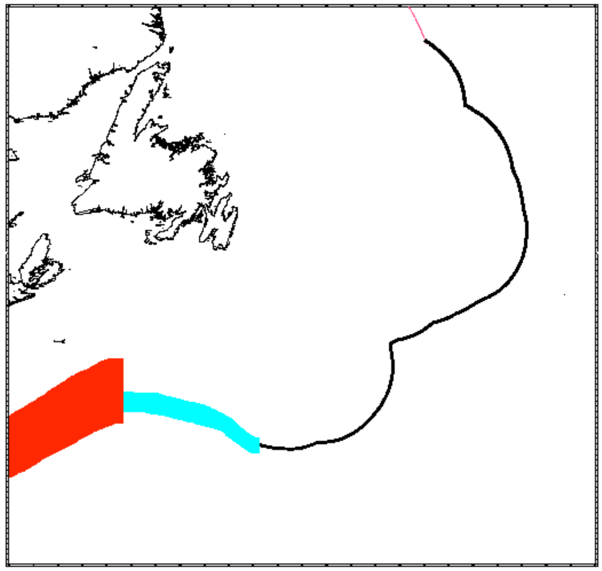

Figure 7.1.1 Diagram showing the horizontal uncertainty of the various components that could make up a hypothetical Outer Limit east of Canada.

Thinnest line is 350M from the baselines, second thinnest line is 100M from 2500 m isobath, third thinnest is 60M from the Foot of the Slope, and widest is a section based on sediment thickness from Foot of the Slope. While the uncertainty represented by the thickness of these lines is to scale, their location is arbitrary and is shown for illustrative purposes only.

7.1.1 "Error estimates" required by the CLCS

The CLCS *Guidelines* take a stance vis-à-vis uncertainty of the various components that make up the outer limit in which it is difficult to discern a central theme. For instance, they insist on error estimates for the bathymetry data used to establish the 2500 m contour, for the Baselines from which the breadth of the Territorial Sea is measured, for gravity data used to determine the location of the Foot of the Slope, and for sediment thickness. However, error estimates do not seem to be required for location of the Foot of the Slope determined on physiographic grounds, for geologic or magnetic data used in evidence to the contrary, or for any of the distance measurements. We thus have a situation where one of the components whose location is the best known, baselines, must have its errors reported, while Foot of the Slope with possible errors

100s or even 1000s times greater need not be reported at all. Nor do the *Guidelines* make any effort to reconcile this range of uncertainty. They do not discuss how uncertainties in the different components combine to affect the outer limit. And nowhere do they say what they will do with the uncertainty values that are reported – is there any uncertainty value that is too great [to be acceptable], for instance.

Table 7.1.1 Showing the elements that can comprise an outer limit under Article 76, an approximate magnitude of the uncertainty achievable for each element and the requirements to report uncertainty embedded in the CLCS Guidelines.
Note that there is no uniform requirement for reporting uncertainty and no advice on what the overall uncertainty should be.

FEATURE	UNCERTAINTY (metres)	CLCS UNCERTAINTY REQUIREMENTS
PLUS 100 nm	1	NOTHING
PLUS 60 nm	1	NOTHING
350 nm	1	NOTHING
BASELINES	10	A PRIORI OR A POSTERIORI ESTIMATES
2500 m ISOBATH	100	A PRIORI OR A POSTERIORI ESTIMATES
Foot of the Slope - GEOMORPHOLOGY	1000	NOTHING
SEDIMENT THICKNESS	1000	EXPECTED RANGES OF ERROR
SEDIMENT THICKNESS	1000	ESTIMATE HORIZONTAL ERROR
F of S -EVIDENCE TO CONTRARY		
GEOLOGY	10 000	NOTHING
MAGNETICS	10 000	NOTHING
GRAVITY	10 000	A PRIORI OR A POSTERIORI ESTIMATES OF RANDOM AND SYSTEMATIC ERRORS

[Monahan, and Wells, 2002]

7.2 Summary

The Convention allows the Outer Constraint to be delineated by straight-line segments joining points that could be up to 60 nm apart. The fixed points are to be fixed points defined by co-ordinates of latitude and longitude, while no guidance is given on accuracy requirements.

On the other hand, the CLCS invents accuracy requirements for some components of Article 76, and ignores others. The *Guidelines* require that a submitting state provide error estimates include error estimates in what seems to be an irrational manner. The key to a Continental Shelf delineation, the Foot of the Slope, need not have its uncertainty reported while other components which are much less important and whose uncertainty is orders of magnitude smaller must be. There is no need to combine individual uncertainties and report uncertainty for the Outer Limit.

Regardless of the demands of Commissions, the physics of measurement and state of development of instrumentation dictate the achievable uncertainty. The values shown in Table 7.1.1 reflect the current state of the art.

CHAPTER 8.
CONCLUSIONS AND NEXT STEPS

8.1 The Boundary-Making Process

UNCLOS undoubtedly created the biggest single boundary-making event in human history. Within a short period of time, not much longer than ten years, two-thirds of the earth's surface will be divided into zones fringing the coasts and over which individual Coastal States exercise varying degrees of sovereignty, with the residual "Area" being administered by the UN in trust for the "common heritage of mankind". The entire seabed of the earth will be consigned to either a national or international authority and subject to its laws and regulations forevermore. As human use of the sea grows, so too will the importance of those boundaries.

The Outer Limit of a Coastal State's Continental Shelf, where one exists, or its Exclusive Economic Zone, where there is no Shelf, forms the boundary of the "Area". A reasonably straightforward measurement of 200 nm establishes the EEZ. Reflecting in part the antipathy that most States felt during the time the Convention was being drafted to what was seen as avaricious expansion into deep water, a sentiment that has waned markedly as more States came to realize that they too could claim a Continental Shelf, its definition is complicated and perhaps contradictory. It reflects, also, the fact that the Convention was written by consensus, not by majority vote, and had to reach a balance of compromises agreeable to all States. Doing so means that in places, and no where more than in Article 76 which defines the Continental Shelf, the language is necessarily imprecise. Diplomats and lawyers are quite accustomed to such imprecision; indeed they thrive on it, but engineers adapt to it only with difficulty.

Boundary-making can be thought of as a three step process. First, the boundary must be *defined* through the words of a treaty or law, which establish the general principals that the boundary shall follow (examples from other boundaries include things like following the center line of a river or proceeding in a certain direction to the height of land). UNCLOS contains such words, and the Articles that deal with boundaries seek to establish the principals on which oceanic boundaries will be established. Objectives of the drafters of the words include securing advantages or at least an equitable share for their State, stability and security through establishing a boundary that will not have to be renegotiated, and universal recognition of the boundary so that it will be respected by all nations. They are <u>not</u> afraid of leaving room for judgement and discretion, nor are they concerned with difficulties in the technical work that will follow to delineate and demarcate the boundary, trusting that science and engineering will perform appropriately to support their hard-won results. And hard-won they were, with UNCLOS III taking the efforts of some 150 states over the fourteen years culminating in signature in 1982.

Delineation, the second step in boundary-making, is the process of applying the words in the definition to maps, charts diagrams, images of the area to determine first where a specific section of the boundary will lie, and second whether there is sufficient data to support the application of the definition to that particular piece of geography. This stage forces a detailed examination of the definition as it applies to what may be called the real world, and may uncover weaknesses or contradictions that will have to be accommodated in the final boundary. Delineation is an iterative process, one in which the boundary is drawn and re-drawn to successively finer levels of detail. For boundaries like the Outer Limit of the Continental Shelf, the iterations will not only seek refinement, they will include examinations of various options with the objective of maximizing the area that a Coastal State can claim.

The third step in boundary-making is demarcation, the physical marking of a boundary, the Great Wall of China being perhaps the greatest and most enduring example on land. Demarcation is very useful; it shows everyone where a certain regime applies and where it does not. At sea, demarcation using physical objects is seldom used: occasionally moored buoys mark the limit of a harbour or other small area. Instead, boundaries must be drawn on charts and stored as coordinates of points marking points on lines. These charts must be given wide distribution and be readily available in order that the world can be informed of the actual location of the boundary.

Within this general context of boundary making, this thesis examined the process of delineating the Outer Limit of the Juridical Continental Shelf.

8.2 The Definition of the Continental Shelf

"Continental Shelf" has been used in marine science since at least 1888 as a term to describe the area of flat or very gently sloping submerged land that fringes the land out to the zone where the gradient changes abruptly and the sea floor drops to abyssal depths. Not all coasts have a Continental Shelf. Although they have been fished for centuries, it is only relatively recently that the seafloor of the continental shelves has been exploited. Drilling for oil may have begun as early as 1925, and today oil and gas recovery is huge and growing, while mining for aggregates, placer gold and diamonds is widespread. Increased economic interest created extended debate at UNCLOS III over who owned the shelves, with the decision in favour of the neighboring Coastal State. A legal definition of the Juridical Continental Shelf was needed so that its extent could be determined, and one was created in Article 76.

The wording of Article 76 reflects the desires of the contending parties at UNCLOS III and the compromise they reached. Broad-margin states, i.e. those with wide physiographic shelves, wanted the definition to permit an extensive shelf, in opposition to the disadvantaged states, those with no physiographic shelves, who would benefit from the Area being as large as possible. Eventually the two sides settled on a position that would see the submerged portions of the continent, a concept already enshrined in law as "the natural prolongation", be available to the Coastal State, with the true oceanic areas being included in the Area. According to prevalent economic knowledge of the time, this granted hydrocarbons to the Coastal State and minerals like “manganese nodules” to the Area.

How to express this intended division in words that all could agree to was the challenge for the treaty-makers. At that time, the conventional model of a shelf came from what is now called a passive margin, which had a horizontal continental shelf terminating at an abrupt shelf break, followed by a Continental Slope descending to a point where it joined the Continental Rise, which sloped downward less steeply to the horizontal Abyssal Plain. On diagrams of this model it appeared that the juncture of the Continental Slope and the Continental Rise, the so-called Foot of the Slope, could mark the division between continental and oceanic crust. However, since it was known that the Continental Rise was composed of sediment and that hydrocarbons occurred only in sediment, it was argued that the actual boundary should include portions of the Rise. This was done in two ways: a State could use either a measurement of 60 nm seawards or the sediment thickness formula which creates a line where the thickness of sedimentary rocks is at least 1 per cent of the shortest distance to the Foot of the Slope. The disadvantaged states, sensing that this could open a loophole for unbounded expansion, forced the inclusion of clauses that would introduce a finite Outer Constraint to the Continental Shelf. A Continental Shelf could not extend beyond the most seaward of a line 350 nm from land, or a line drawn 100 nm seaward of the 2500 m depth contour. The configuration of the 2500 m contour around a few States, notably Iceland, would still permit unlimited expansion, and so a clause restricting the outer Constraint to 350 nm over "submarine ridges" was introduced.

For completeness and to ensure no misunderstanding, Article 76 provides a definition of the Foot of the Slope:

> In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.

Clearly the wording was strongly influenced by the oversimplified model discussed above. It also includes a device often used in treaties and laws, the "evidence to the contrary" clause, without defining what constitutes evidence to the contrary.

Perhaps being aware of the enormity of the task ahead of Coastal States, perhaps for other reasons discussed below, Article 76 does not demand that the Outer Limit be delineated everywhere. Only "straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by co-ordinates of latitude and longitude" are required.

Disadvantaged states still required assurances that broad margin states would not overreach the intended distribution of the world sea floor. They established a process whereby a Coastal State would have to actively establish its Continental Shelf through submitting information on its limits to a body created by UNCLOS, the Commission on the Limits of the Continental Shelf (CLCS). The sovereign right of the Coastal State to establish its boundaries is not eliminated; however, it shall do so on the basis of the recommendations made to it by the

CLCS. The CLCS has been seen as a watchdog by some, and seen in a more encompassing role of “legitimator”, the body that makes claims legitimate by McDorman, [2002]. The general model for establishing boundaries of “definition – delineation – demarcation” may have been complicated by the creation of the CLCS, although it can be argued that it is beneficial for the Coastal State to demonstrate to the world that it fits the definition in Article 76 by submitting its boundary to an International body. Nevertheless, a complication has been introduced by the CLCS producing *Guidelines* regarding the type and amount of data they require: they may have overstepped their mandate in parts of the document, and possibly created confusion between interpretations of the Convention and themselves.

Article 76 also gives an instruction on demarcation, where it requires the Coastal State to deposit with the Secretary-General of the United Nations charts and relevant information describing the outer limits and requires the Secretary-General to give publicity to the limits.

8.3 The Delineation of the Continental Shelf

8.3.1 The Need for a Model

Coastal States will consider whether or not their geography allows them to delineate a Continental Shelf. Those who clearly cannot are those whose EEZ terminates against that of an opposite or adjacent state. All others will probably run through at least a preliminary analysis of their situation to determine whether they can prepare a case for demarcation. When the first States commenced doing so they were faced with understanding Article 76 within the context of their own geography, examining existing data to determine whether it was sufficient, deciding which features they wish to attempt to claim, planning for collecting additional data, assembling the data into a supported and defensible claim and submitting a case. This was beyond the technological and/or financial capabilities of some Coastal States, and indeed some have asked for assistance.

When first entering the fray, Coastal States quickly realized that although Article 76 defines a Continental Shelf limit it does not provide a set of instructions or framework on how an Outer Limit is to be delineated. The rules of a game are not a set of instructions on how to play that game. Nor is Article 76 simple and easily adhered to. There was a need for a model of the process to be followed, and one was developed as part of this project. While this model was being produced, the CLCS distributed its draft *Guidelines* giving rules on the types of data that it would find acceptable. The final version of the *Guidelines* does contain some flow diagrams of the steps that might be followed, possibly based on the model developed herein.

8.3.2 Fundamental Tools

The exercise of delineation will be carried out on some form of base map, be it paper or digital. Better yet would be a full GIS, like CARIS LOTS.

Base maps should not be complicated; initially all that is needed is shoreline, bathymetry and bilateral boundaries with nearby States. Shoreline and bathymetry are shown on published bathymetry maps and grids, which are readily available although the quality, scale and coverage vary considerably. (One of the tasks will be to decide if the available bathymetry is accurate and complete enough to use in a submission). Most States have already promulgated their 200 nm EEZ, and most have deposited Baselines with the Secretary-General of the UN so these can be added to the base map. (The numbers are constantly changing, and the most recent are available from the UN at http://www.un.org/Depts/los/convention_agreements/convention_agreements.htm). This much information is sufficient to perform a perfunctory analysis – where is the 200 nm line in relation to the physical shelf? If there is only a narrow shelf, there may be no value in proceeding further. The minimum condition for establishing a Continental Shelf is that the Foot of the Slope be at least 140 M from the Baselines. Even small-scale bathymetry maps will permit saying that it definitely is further seaward, that it is impossible to tell, or that it is definitely landward. The first two indicate that proceeding to more detailed investigation is warranted: the third means either that there is no Continental Shelf or that the Foot of the Slope will have to be established using evidence to the contrary.

At this stage, too, it will likely be possible to make a preliminary investigation of the alternative Outer Constraint lines. The biggest concern is whether the 2500 m isobath plus 100 nm line will be used. If it clearly lies within 350 nm, there will be little need to spend any further effort on it, while a location beyond 350 probably means that a further refinement of the bathymetry will be needed.

8.3.2.1 Baselines from which the breadth of the Territorial Sea is measured

Baselines can be revised and some States regularly revise theirs. Other boundaries based on them (Territorial Sea, EEZ and 350 nm Constraint) will be fixed as their locations were originally deposited with the Secretary General of the UN, and will not be revised later if a Baseline is changed. Consequently, it may be to a state's advantage to revisit its Baselines should it appear that the 350 nm Constraint will be used.

The concept of using baselines to separate land from sea was codified in UNCLOS I. Baselines are either normal, which is the low-water line as shown on charts or straight lines joining points along the shore or a combination of both. Only a few points on the Baselines will be used to construct the 350 nm Constraint, and the selection of points that will generate the largest area for the Coastal State may involve a few iterations.

8.3.2.2 Available Data Sets

One of the major and as yet unresolved questions is determining how much data is required to substantiate locating a boundary. The definition does not address this question directly, but the requirement to delineate the Outer Limit at points up to 60 nm apart can be interpreted to mean that lines of data 60 nm apart were all that the drafters of the Convention envisioned as being necessary.

At the other end of the spectrum, a number of countries have undertaken special Law of the Sea surveys and collected very densely-spaced data along their Continental Slopes. They have not yet submitted this data, and one argument for collecting it was that a surfeit of data would permit selection of the points most beneficial to the Coastal State. In the one submission to date, Russia's, synthetic tracks which are lines along which profiles have been generated at 60 nm intervals were used. The fate of this submission is unclear at the time of writing.

The position the CLCS takes on the quantities of data necessary is captured in the *Guidelines* Paragraph 9.2.2:

> Whereas only a part of it [bathymetric data] may be needed in the main body, the full bathymetric database will be regarded as an essential component of the supporting scientific and technical data.

In other words, they want all the data that the Coastal State used in the delineation process, even though it may not be needed for demarcation.

During the preliminary stages, Coastal States will use whatever data are available, and the amount of data will vary considerably. Some will have a considerable amount of data within their area of interest, collected previously for defense, navigation, research and mineral exploration purposes. Others will have little. The data that does exist may have been organized in national data bases, and maps published from it, or it may exist in disparate locations requiring a considerable effort to assemble to common points of reference. Additionally, data collected close to any State may have been submitted to one of the World Data Centres for Marine Geology and Geophysics. There it would have been incorporated into one of the readily available and frequently updated collections like the Global Trackline Geophysical Data Base (GEODAS). Data available includes echo-sounding, seismic reflection, gravity collected from space and ships, magnetic profiles and data from the international Ocean Drilling Programme. While in places this may create a seeming abundance of data, there are major areas with no data at all. Furthermore, little or none of the data were collected for Law of the Sea purposes, so that its location and density will rarely be optimal. Nevertheless, there are raw data and derived products like maps available for an acceptable first look.

For instance, bathymetry of all the world ocean has been mapped through an international collaborative exercise known as the General Bathymetric Chart of the Oceans (GEBCO) that produces contour maps. This is a good starting point for any preliminary investigation, although where more recent or better scale maps exist, they should be used. Gridded bathymetric data are available in the ETOPO-5 data set, with depths calculated as values at regular grid points. "Satellite bathymetry", or more properly Predicted Topography, is available for all but the polar regions and shows the longer wavelength features of the seafloor. All these can be used during the early stages of delineation. A comparison of the three bathymetric data sets with new MBES data performed as part of this thesis showed that the publicly available data is of high enough quality to permit production of credible early versions of maps. Multibeam data adds a considerable amount of short wavelength detail that will be valuable as the process of refining the Outer Limit continues. More detailed bathymetry may be needed for the Outer Constraint.

8.3.3 A look at the Outer Constraint

The 2500 m isobath plus 100 nautical miles will form the Outer Constraint in some areas. For much of the ocean, the 2500 m contour has not been mapped in detail, yet arcs 100 nm in length swung from it may become the boundary of a Coastal State. How well does it need to be known? An exact location for the Outer Constraint only becomes important when it forms the Outer Limit. When it is simply a line well beyond where the Outer Limit can lie, uncertainty in its location need be of lesser concern.

Where the 2500 m contour contributes to the Outer Limit, it does so by providing the foci of arcs 100 nm long, and the foci can be up to 60 nm apart. A Coastal State will want to determine those points along the isobath that will produce a maximum area. Existing contours produced from single beam echo sounder tracks, derived grids or satellite “predictions” are generally smooth and occupy a zone of uncertainty 10-20 km wide. MBES surveys produce a much more detailed contour, one that generally lies within the zone of uncertainty of the SBES – derived contours, occasionally falling landward or seaward from the zone. Careful selection of the most seaward of these as points from which 100 nautical miles can be measured could lead to a larger Continental Shelf for a Coastal State. Unfortunately only limited areas have been surveyed using multibeam, although some Coastal States have undertaken MBES programs specifically to help delineate their Continental Shelves.

Not all 2500 m contours lie on simple, planar Continental Slopes. There are areas with off-lying "submarine elevations" surrounded by 2500 m isobaths that may or may not form part of the "natural prolongation" of a Coastal State. States will argue that these elevations be included within the area of a possible Continental Shelf. Their case will involve trying to demonstrate that the elevation is a natural part of the continental margin, and will invoke geological and geophysical reasoning. Since Article 76 is vague on what an elevation is, and in particular what a ridge is, the CLCS has ruled that each case will be decided on its own merit.

8.3.4 The Heart of Continental Shelf Delineation, the Foot of the Slope

Delineating the Foot of the Slope means trying to map a feature that may or may not exist, exist that is in the sense that one could stand with feet astride it and point to it, as one could with other features used in other boundary definitions, for example the height of land. However, since it is defined as the maximum change in gradient, unless a section through the Continental Slope and Rise is an arc of constant radius, at some scale the Foot of the Slope will exist. The nub of the problem is thus how to transform from the small-scale (or even scale-less) concept embedded in the definition to the necessarily large-scale expression required for delineation. On large-scale bathymetry maps, it is sometimes possible to sketch in a Foot of the Slope based on spacing between the contours. On smaller scale maps of the same area, the same feature cannot be found. Multibeam images of the same piece of seafloor can have so much detail that several steps and changes of slope can be seen in a localized area.

Profiles across the margin exhibit the same behavior. On a profile reproduced at a small horizontal scale, it may be possible to visually select the maximum change in gradient. Displaying the same profile at larger scales may reveal the presence of several maxima.

In the *Guidelines*, the CLCS states that it will not accept a Foot of the Slope selected on purely visual grounds and that some mathematical technique must be used. One such mathematical technique would be to calculate the second derivative continuously along a profile: CARIS LOTS will do so, yet most profiles show several maxima. Perhaps the scale of profiles is too large. Others have tried various surface-fitting approaches to a large section of margin, and claim varying degrees of success. Readers may not share the authors' enthusiasms for the results. These produce a surface that can have more than one solution and is another step removed from the actual sea floor; it remains to be seen how the CLCS will react.

The Russian submission used yet another approach, and one that defined its own scale. From whatever depth data were available, a regular grid of depths was calculated. Synthetic profiles were created across the grid. The gradient between successive pairs of points was calculated along each profile, and the point whose adjoining gradients showed the greatest difference was selected as the Foot of the Slope. Scale is related to the spacing between points, which was 2500 m. This method also created several maxima, of which one was chosen by "geomorphological analysis" (i.e. visually).

As an exception to the general rule for defining the Foot of the Slope as "the point of maximum change in the gradient at its base", the Foot of the Slope can be determined using unspecified "evidence to the contrary." It is generally believed that geological arguments can be used to establish the ocean/continent boundary and treat that as the Foot of the Slope line for measurement purposes. The *Guidelines* insist that it must be proven that a morphological Foot of the Slope does not exist before this clause can be invoked. They also require that before a Foot of the Slope can be delineated, the region defined as the *base* of the continental slope must be identified.

8.4 Uncertainty in demarcating the boundary

Uncertainty in the different elements that might appear in a Continental Shelf delineation range from metres for measurements of 60, and 350 nm, to tens of metres for Baselines, to hundreds of metres for the 2500 m isobath, to thousands of metres for Foot of the Slope and sediment thickness, to tens of thousands of metres for Foot of the Slope determined by evidence to the contrary. The most certainly delineated boundary will be that where the Outer Constraint forms the Outer Limit, while that delineated by evidence to the contrary will be the most uncertain. Demands for uncertainty information in the *Guidelines* is inconsistent and adds little assurance of the value of the process.

8.5 Next Steps

Ocean mapping was considerably advanced by the drafting and signing of UNCLOS, since it spawned an examination of what could be done to delineate the Continental Shelf under the definition of Article 76. Ratification of the Convention was another motivator, leading to a number of States collecting data at sea, and the development of tools to aid in its analysis. The third major surge came on the heels of the issuance of the *Guidelines*, forcing a reanalysis of some of what had been learned to date. The first submission to the CLCS, that of the Russian Federation, has the potential to further influence and advance Continental Shelf mapping, but only if the submission and the resulting recommendations are made public. Under the current rules, it is up to the submitting state whether or not the material becomes publicly available: at the time of writing, there is an unconfirmed report that Russia will hold a workshop next year to discuss its submission. While waiting with hope that this will prove to be true, there are several areas that can be developed to advantage. These include the following:

a) Building a data base of marine boundaries

b) Refining our understanding of the significance of the requirement to delineate the outer Limit by straight lines not exceeding 60 nautical miles in length

c) Determining which elements of Article 76 will apply in each area of Canada

d) Improving the model for finding the Foot of the Slope.

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Appendix I Article 76 of UNCLOS

ARTICLE 76. DEFINITION OF THE CONTINENTAL SHELF (In its entirety, from the Convention)

1. The continental shelf of a coastal State comprises the sea-bed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.

2. The continental shelf of a coastal State shall not extend beyond the limits provided for in paragraphs 4 to 6.

3. The continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the sea-bed and subsoil of the shelf, the slope and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof.

4. (a) For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either:

(i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope; or

(ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope.

(b) In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.

5. The fixed points comprising the line of the outer limit of the continental shelf on the sea-bed, drawn in accordance with paragraph 4 (a)(i) and (ii), either shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or shall not exceed 100 nautical miles from the 2,500 metre isobath, which is a line connecting the depth of 2,500 metres.

6. Notwithstanding the provisions of paragraph 5, on submarine ridges, the outer limit of the continental shelf shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured. This paragraph does not apply to submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks and spurs.

7. The coastal State shall delineate the outer limits of its continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by co-ordinates of latitude and longitude.

8. Information on the limits of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured shall be submitted by the coastal State to the Commission on the Limits of the Continental Shelf set up under Annex II on the basis of equitable geographical representation. The Commission shall make recommendations to coastal States on matters related to the establishment of the outer limits of their continental shelf. The limits of the shelf established by a coastal State on the basis of these recommendations shall be final and binding.

9. The coastal State shall deposit with the Secretary-General of the United Nations charts and relevant information, including geodetic data, permanently describing the outer limits of its continental shelf. The Secretary-General shall give due publicity thereto.

The provisions of this article are without prejudice to the question of delimitation of the continental shelf between States with opposite or adjacent coasts.

Appendix II Commission on the Limits of the Continental Shelf (CLCS)

ANNEX II. *(to UNCLOS)* **COMMISSION ON THE LIMITS OF THE CONTINENTAL SHELF** *(CLCS)*

Article 1

In accordance with the provisions of Article76, a Commission on the Limits of the Continental Shelf beyond 200 nautical miles shall be established in conformity with the following articles.

Article 2

1. The Commission shall consist of 21 members who shall be experts in the field of geology, geophysics or hydrography, elected by States Parties to this Convention from among their nationals, having due regard to the need to ensure equitable geographical representation, who shall serve in their personal capacities.

2. The initial election shall be held as soon as possible but in any case within 18 months after the date of entry into force of this Convention. At least three months before the date of each election, the Secretary-General of the United Nations shall address a letter to the States Parties, inviting the submission of nominations, after appropriate regional consultations, within three months. The Secretary-General shall prepare a list in alphabetical order of all persons thus nominated and shall submit it to all the States Parties.

3. Elections of the members of the Commission shall be held at a meeting of States Parties convened by the Secretary-General at United Nations Headquarters. At that meeting, for which two thirds of the States Parties shall constitute a quorum, the persons elected to the Commission shall be those nominees who obtain a two-thirds majority of the votes of the representatives of States Parties present and voting. Not less than three members shall be elected from each geographical region.

4. The members of the Commission shall be elected for a term of five years. They shall be eligible for re-election.

5. The State Party which submitted the nomination of a member of the Commission shall defray the expenses of that member while in performance of Commission duties. The coastal State concerned shall defray the expenses incurred in respect of the advice referred to in article 3, paragraph 1(b), of this

Annex. The secretariat of the Commission shall be provided by the Secretary-General of the United Nations.

Article 3

1. The functions of the Commission shall be:

(a) to consider the data and other material submitted by coastal States concerning the outer limits of the continental shelf in areas where those limits extend beyond 200 nautical miles, and to make recommendations in accordance with article 76 and the Statement of Understanding adopted on 29 August 1980 by the Third United Nations Conference on the Law of the Sea;

(b) to provide scientific and technical advice, if requested by the coastal State concerned during the preparation of the data referred to in subparagraph (a).

2. The Commission may cooperate, to the extent considered necessary and useful, with the Intergovernmental Oceanographic Commission of UNESCO, the International Hydrographic Organization and other competent international organizations with a view to exchanging scientific and technical information which might be of assistance in discharging the Commission's responsibilities.

Article 4

Where a coastal State intends to establish, in accordance with Article76, the outer limits of its continental shelf beyond 200 nautical miles, it shall submit particulars of such limits to the Commission along with supporting scientific and technical data as soon as possible but in any case within 10 years of the entry into force of this Convention for that State. The coastal State shall at the same time give the names of any Commission members who have provided it with scientific and technical advice.

Article 5

Unless the Commission decides otherwise, the Commission shall function by way of sub-commissions composed of seven members, appointed in a balanced manner taking into account the specific elements of each submission by a coastal State. Nationals of the coastal State making the submission who are members of the Commission and any Commission member who has assisted a coastal State by providing scientific and technical advice with respect to the delineation shall not be a member of the sub-commission dealing with that submission but has the right to participate as a member in the proceedings of the Commission concerning the said submission. The coastal State which has made a submission to the Commission may send its representatives to participate in the relevant proceedings without the right to vote.

Article 6

1. The sub-commission shall submit its recommendations to the Commission.

2. Approval by the Commission of the recommendations of the sub-commission shall be by a majority of two thirds of Commission members present and voting.

3. The recommendations of the Commission shall be submitted in writing to the coastal State which made the submission and to the Secretary-General of the United Nations.

Article 7

Coastal States shall establish the outer limits of the continental shelf in conformity with the provisions of article 76, paragraph 8, and in accordance with the appropriate national procedures.

Article 8

In the case of disagreement by the coastal State with the recommendations of the Commission, the coastal State shall, within a reasonable time, make a revised or new submission to the Commission.

Article 9

The actions of the Commission shall not prejudice matters relating to delimitation of boundaries between States with opposite or adjacent coasts.

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